The Web Service Modeling Language WSML

An Overview

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Outline

Introduction
  Recap of WSMO
  Languages for Semantic Web Services

WSML Language Variants

WSML Language Elements
  Conceptual Syntax
  Logical Expression Syntax

WSML Exchange Syntaxes
  WSML XML Serialization
  WSML RDF Serialization

Conclusions
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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

Goals

Ontologies

Mediators

Web Services
The Web Service Modeling Language WSML

Introduction

Recap of WSMO

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
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Goals

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

- i. Static knowledge (ontologies)
- ii. Functional description
- iii. Behavioral description
- iv. Non-functional properties

Semantic Web Services

Semantic Web

Languages for Semantic Web Services

The Web Service Modeling Language WSML

Introduction

Languages for Semantic Web Services
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
Why not use OWL?
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- Semantic Web is not only about Description Logics!
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- “Inferring style” restrictions of OWL not useful in all settings
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- WSML investigates use of
  - Logic Programming
  - Description Logics

in common framework
Why not use OWL?

- Semantic Web is not only about Description Logics!
- “Inferring style” restrictions of OWL not useful in all settings
- WSML investigates use of
  - Logic Programming
  - Description Logics
  in common framework
- WSML-DL close to OWL DL
Why not use OWL?

- Semantic Web is not only about Description Logics!
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- WSML investigates use of
  - Logic Programming
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    in common framework
- WSML-DL close to OWL DL
- Interoperation between LP and DL through common subset
Why not use OWL?

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- WSML investigates use of
  - Logic Programming
  - Description Logics
  in common framework
- WSML-DL close to OWL DL
- Interoperation between LP and DL through common subset
- Expressive integration of DL and LP topic of ongoing research (Eiter et al., KR2004; Rosati, KR2006)
WSML and the Semantic Web

- WSML-Full
- WSML-DL
- WSML-Flight
- WSML-Core
- WSML-Rule
- DLP bit
- OWL
- Rules
- FOL ++
- RDF(S)
- XML
- Unicode
- URI
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WSML Language Variants

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

Expressiveness:

Logic Programming  Description Logics
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
The Web Service Modeling Language WSML

WSML Language Variants

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
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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

```xml
wsmlVariant "http://www.wsmo.org/wsml/wsml-syntax/wsml-flight"

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

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

etc...
```
Prologue
By Example

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

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

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

etc...
Prologue
By Example

```
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/" }

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

etc...
```
Prologue
By Example

```
wsmlVariant   "http://www.wsmo.org/wsml/wsml-synta/x/wsml-flight"

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
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Ontologies

Header

[.. prologue ..]

```
onontology "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

concepts 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 `subRelationOf`)

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

nfp
dc#description hasValue ”Marriage is a relation between two persons, which are the participants in the marriage, and the date in the marriage.”

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

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

```wsml
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

```xml
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 \( ?x, ?y, \ldots \)
  precondition
    definedBy
      \ldots
  postcondition
    definedBy
      \ldots
  assumption
    definedBy
      \ldots
  effect
    definedBy
      \ldots
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

\texttt{goal} "http://www.example.org/exampleGoal"

\texttt{capability}

... 

\texttt{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

wgMediator _”http://www.example.org/exampleMediator”

source _”http://www.example.org/exampleGoal”
target _”http://www.example.org/exampleService”

usesService _”http://www.example.org/mediationService”
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WSML Language Elements

Logical Expression Syntax

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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
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].
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.
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]).
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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<th>DL</th>
<th>Flight</th>
<th>Rule</th>
<th>Full</th>
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<td>-</td>
<td>X</td>
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<td>Existential Quantification</td>
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<td>Meta Modeling</td>
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<td>Default Negation (<strong>naf</strong>)</td>
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<td>-</td>
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<td>LP implication</td>
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<td>Integrity Constraints</td>
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<td>Unsafe Rules</td>
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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−syntax#” >
<wsml xmlns="&wsml;”
   variant =”http://www.wsmo.org/wsml/wsml−syntax/wsml−flight” >
   <importsOntology>
      http://www.wsmo.org/ontologies/location
   </importsOntology>
   <concept name="&ex;Person” >
      <nonFunctionalProperties>[..]</nonFunctionalProperties>
      <attribute name="&ex;hasName” type="constraining” >
         <range>&wsml;string</range>
         <maxCardinality>1</maxCardinality>
      </attribute>
   [..]
   </concept>
[..]
</wsml>
```
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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

```xml
<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 _:nfp1
_: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 _:att1
_:att1 wsml#attribute ex#hasName
_:att1 wsml#ofType xsd#string
_:att1 wsml#maxCardinality "1"^^xsd:integer
<http://www.example.org/ontology> wsml#hasAxiom
  ex#personUncle
ex#personUncle rdfs#isDefinedBy
  "<impliedByLP>..</impliedByLP>"^^rdf#XMLLiteral
```
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Conclusions
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
Ongoing and Future Work

- Integration of LP and DL
  - Incorporation in WSML framework
- WSML-Full semantics
  - First-Order Autoepistemic Logic
- RDF Representation of WSML
- Semantics of Functional Description
- Language for Behavioral Description
- Uses of Non-Functional Properties
- Grounding to existing Web Service Standards
WSML resources
http://www.wsmo.org/wsml/wsml-syntax#