

A motivating introduction to

Semantic Web and Semantic Web Services

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Overview

- ▶ The Semantic Web
 - ▶ Idea
 - ▶ “Layer cake”
 - ▶ RDF and OWL
- ▶ Web Services
 - ▶ Components of SOA
 - ▶ SOAP, WSDL, UDDI
- ▶ Towards Semantic Web Services
 - ▶ Aspects
 - ▶ Usage Tasks
- ▶ Approaches
 - ▶ OWL-S
 - ▶ WSMO
 - ▶ SWSF
 - ▶ WSDL-S

The Semantic Web



<http://imdb.com>

<http://badmovies.org>

- ▶ The Semantic Web promises machine-readable **metadata** annotations of websites allowing to combine and query their content, draw additional inferences, just like you'd deal with a huge database.
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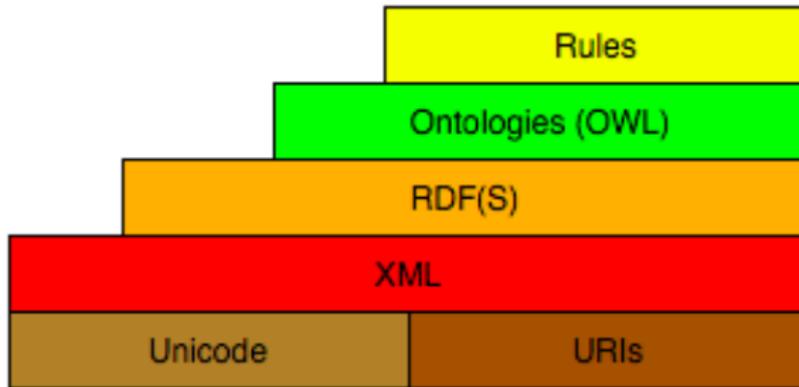
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- ▶ I want to express **taxonomies** such as *"Science-fiction movies are movies."*
- ▶ Besides metadata **facts**, I want to express more complex **rules** such as for instance: *"All movies listed on badmovies.org are rated bad."*



The W3C's Semantic Web “layer cake”



- ▶ XML is the basis
- ▶ RDF is a graph-based datamodel for describing meta-data
- ▶ OWL and Rules shall provide possibility to infer additional knowledge

Remark: Semantic Web is not only about combining Web meta-data, but about **data integration** in general (not a new issue)!

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- ▶ Simply: Additional rules, descriptions of a data model in a formal language, related: UML, EER, etc.
- ▶ What makes ontologies different from datamodels is :
Consensual!
- ▶ OWL/RDF are only a languages for this, i.e. Ontologies and the semantic Web only work if people **share** ontologies.

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- ▶ Again: automatd reasoning and a bit of logic as the foundations!

From static to dynamic



http://www.renfe.es

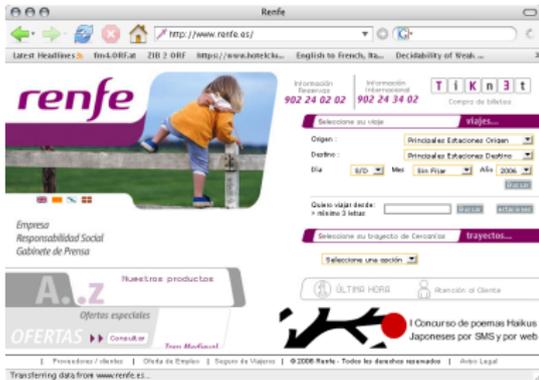


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Web Services (1/2)

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- ▶ What is “webbish” about Web services?
 - ▶ Using Web protocols such as HTTP, allow easy integration with exiting Web server technologies as “application servers”
 - ▶ Strictly relying on XML as message exchange format

Web Services (2/2)

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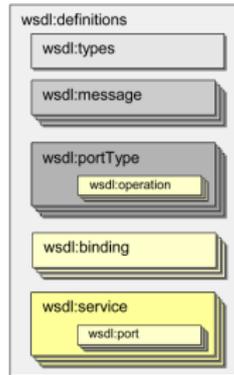
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- ▶ Standardization bodies support it: W3C, OASIS (Organization for the Advancement of Structured Information Standards)
- ▶ “Global Players” (IBM, Microsoft, BEA, etc.) collaborate!

⇒ High potential!

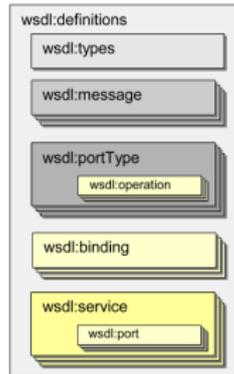
Web Services - SOAP

- ▶ Messaging framework for peers communicating XML messages.
- ▶ packs an XML message in a so-called SOAP “envelope” which can contain additional fault handling and routing information, etc.
- ▶ Most common protocol binding is on top of HTTP, but also other possible.

Web Services - WSDL (1/2)

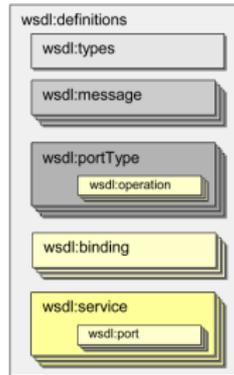


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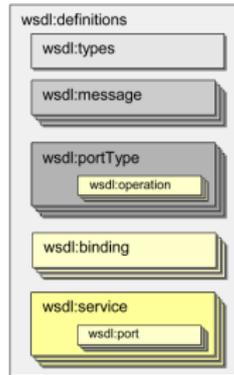
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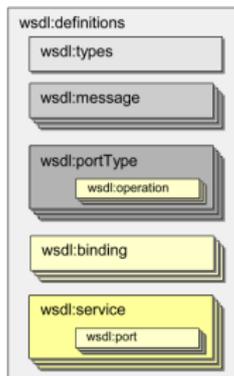
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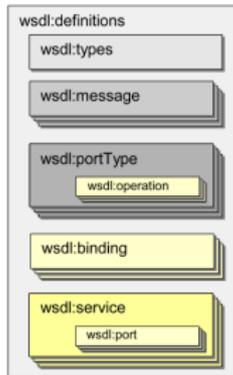
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- ▶ Define the service *endpoint* address where the service can be invoked.

Web Services - WSDL (2/2)

If you wanna play around, see e.g.: <http://www.xmethods.net/>

```
[...]  
<wsdl:types>  
  [...]  
  <s:element name="GetWeather">  
    <s:complexType>  
      <s:sequence>  
        <s:element minOccurs="0" maxOccurs="1" name="CityName" type="s:string" />  
        <s:element minOccurs="0" maxOccurs="1" name="CountryName" type="s:string" />  
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    </s:complexType>  
  </s:element>  
  [...]  
</wsdl:types>  
  
<wsdl:message name="GetWeatherIn">  
  <wsdl:part name="parameters" element="tns:GetWeather" />  
</wsdl:message>  
[...]  
  
<wsdl:portType name="GlobalWeather">  
  <wsdl:operation name="GetWeather">  
    <wsdl:input message="tns:GetWeatherSoapIn" />  
    <wsdl:output message="tns:GetWeatherSoapOut" />  
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<wsdl:binding name="GlobalWeatherSoap" type="tns:GlobalWeather">  
  <soap:binding transport="http://schemas.xmlsoap.org/soap/http" style="document" />  
  <wsdl:operation name="GetWeather">  
    <soap:operation soapAction="http://www.webservicex.NET/GetWeather" style="document" />  
    <wsdl:input><soap:body use="literal" /></wsdl:input>  
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Web Services - UDDI

UDDI is

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- ▶ a data model for service and business entities
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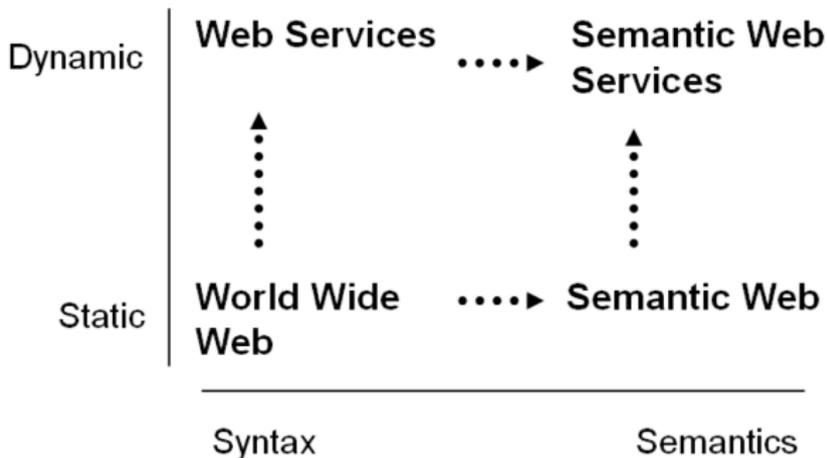
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Would make sense to use the similar metadata format, for annotating services, WSDL operations, input/output messages, etc. to describe their meaning.

What's missing with Web Services?

By combination of Web services with Semantic Web technologies, we hope to achieve a higher degree of automatization of discovery, composition, invocation, etc.



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 - ▶ **Execution:** Invoke services following programmatic conventions
 - ▶ **Monitoring:** Control the execution process

Aim

- ▶ Semantically enhanced repositories
- ▶ Tools and platforms that semantically enrich current Web service descriptions and facilitate:
 - ▶ **Discovery:** Locate different services suitable for a given task
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 - ▶ **Replacement:** Facilitate substitution of services by equivalent ones

Representational Aspects of Semantic service description

Should describe information necessary to enable discovery, composition, execution, etc.

1. General *service classifications* using taxonomies
2. *pre- and postconditions*, functional aspects (What does the service provide under which conditions?)
3. *behavior/protocol* description of the service (How to interact with the service in order to achieve a certain functionality?)
4. non-functional aspects (QoS, cost, availability, etc.)

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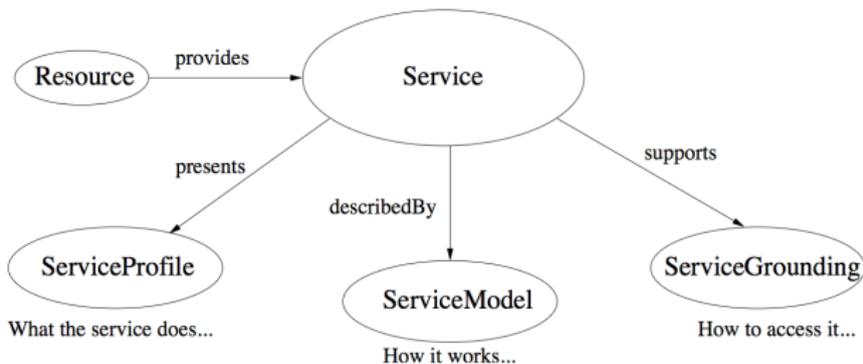
Approaches:

- ▶ OWL-S
- ▶ WSMO
- ▶ SWSF
- ▶ WSDL-S

OWL-S

<http://www.w3.org/Submission/OWL-S/>

- ▶ OWL-S is an OWL ontology to describe Web services, i.e. a metadata vocabulary for services
- ▶ Main components of a service described in three sub-ontologies:



OWL-S Service Profile

Two main uses:

- ▶ Advertisements of Web Services capabilities (non-functional properties, QoS, Description, classification, etc.)
- ▶ Request of Web services with a given set of capabilities

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Classes/Properties:

- Preconditions** Set of conditions that should hold prior to service invocation
 - Inputs** Set of necessary inputs that the requester should provide to invoke the service
 - Outputs** Results that the requester should expect after interaction with the service provider is completed
 - Effects** Set of statements that should hold true if the service is invoked successfully.
- Service type** What kind of service is provided (eg selling vs distribution)
- Product** Product associated with the service (eg travel vs books vs auto parts)

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Logics: *outside OWL!* Reference to Preconditions/Effects can refer to KIF, DRS, SWRL

OWL-S Service model

Main uses:

- ▶ Define Process Model: Describes how a service works. Internal processes of the service Specifies service, interaction protocol
- ▶ Specify abstract messages (can be inherited or refined from profile): ontological type of information transmitted
- ▶ Facilitate Web service invocation, Composition of Web services Monitoring of interaction

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Classes/Properties:

- ▶ Each process model is built from atomic and composite processes
- ▶ **Atomic processes:**
 - Inputs** the inputs that the process requires
 - Preconditions** the conditions that are required for the process to run correctly
 - Outputs** the information that results from (and is returned from) the execution of the process
 - Results** a process may have different outcomes depending on some condition. Result consists of: **Condition, Constraints**, real world **Effects**.
- ▶ **Composite processes:** OWL-S defines a simple treelike “workflow language” for defining processes consisting of sequence, loop, switch, parallel execution, etc. (**control flow**) and **dataflow** etc.

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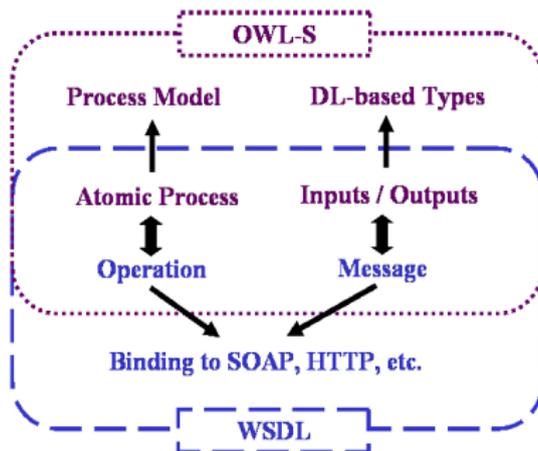
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Problem: OWL (DL) doesn't capture semantics of workflow, conditions, etc.

OWL-S Grounding

Shall close the GAP to “traditional” Web Services world, allow linking to arbitrary WSDL descriptions.



Possible problem: Simple mapping would still allow syntactic differences.

Solution: Last version of OWL-S allows to e.g. link to XSLT to link between ontological representation and XSD defined messages in WSDL.

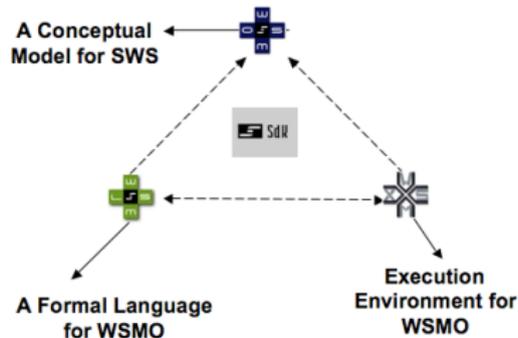
WSMO

<http://www.w3.org/Submission/WSMO/>

European Effort, concept based in PSMs, UMPL, etc. More a framework for SWS annotation than an ontology

Tries to solve some of the OWL-S problems:

- ▶ WSMO is not an ontology in OWL, WSMO defines an own ontology language.
- ▶ Decouple provider and requester view.
- ▶ Decouple Interface from Implementation: distinguish between internal process and externally observable behavior.
- ▶ make mediation a first-class object



Still, many similarities with the OWL-S model.

WSMO top level concepts

Objectives that a client may have when consulting a Web Service



WSMO ontologies

- ▶ Define terminology (classes, attributes, axioms on terminology) used by a web service.
- ▶ Language: WSML
 - ▶ Ontology language in WSML closer to LP than OWL.
 - ▶ A more expressive language for expressing conditions, axioms, than OWL.
 - ▶ WSML (under development) is not only an ontology language but shall comprise a language for expressing all of WSMO.

Properties:

- ▶ Imported Ontologies: import existing ontologies where no heterogeneities arise
- ▶ Used mediators: OO Mediators (ontology import with terminology mismatch handling)
- ▶ “Standard” Ontology Notions: Concepts, Attributes, Relations, Functions, Instances, Axioms

WSMO services/goals

Define the provided/requested:

- ▶ capability
- ▶ interfaces

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Imported Ontologies

Used mediators OOMediators, WWMediators, WGMediators.

Pre-conditions What a web service expects in order to be able to provide its service. They define conditions over the input.

Assumptions Conditions on the state of the world that has to hold before the Web Service can be executed and work correctly, but not necessarily checked/checkable.

Post-conditions describe the result of the Web Service in relation to the input, and conditions on it.

Effects Conditions on the state of the world that hold after execution of the Web Service (i.e. changes in the state of the world)

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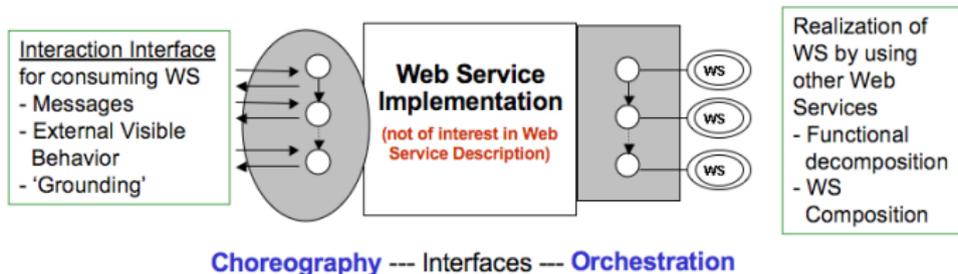
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Interfaces: WSMO distinguishes *choreography* and *orchestration* interfaces

WSMO service/goal interfaces:

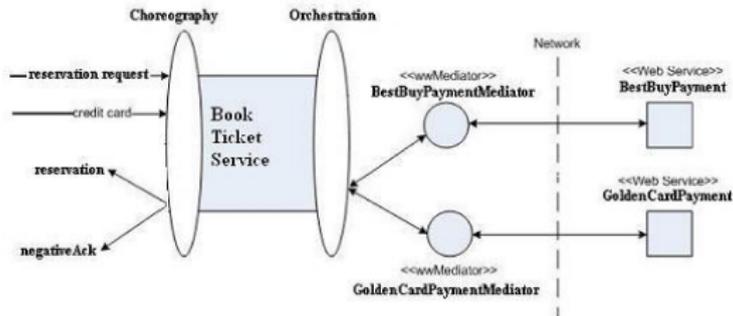
No workflow language but an automaton (abstract state machine) shall define the control and data flow. Final syntax still under discussion.



"Grounding" idea similar to OWL-S: input/output messages references to WSDL message-operation pair

WSMO service/goal interfaces:

No workflow language but an automaton (abstract state machine) shall define the control and data flow. Final syntax still under discussion.



A simple example.

- ▶ **Choreography interface:** externally observable behavior of the service
- ▶ **Orchestration interface:** which other services will be called by this service in order to fulfill its capability.

WSMO Services

Requester view, dual to Web service annotations:

- ▶ provide/guarantee non-functional properties
- ▶ import Ontologies
- ▶ use Mediators
- ▶ provide a Capability
- ▶ provide an Interface

WSMO Goals

Requester view, dual to Web service annotations:

- ▶ request non-functional properties
- ▶ import Ontologies
- ▶ use Mediators
- ▶ request a Capability
- ▶ request an Interface

WSMO Mediators (1/2):

Resolve mismatches in service interaction/between service annotations. Different levels of Heterogeneity:

- (1) Data Level: mediate heterogeneous Data Sources
- (2) Protocol/Process Level: mediate heterogeneous Communication Patterns and Business Processes.

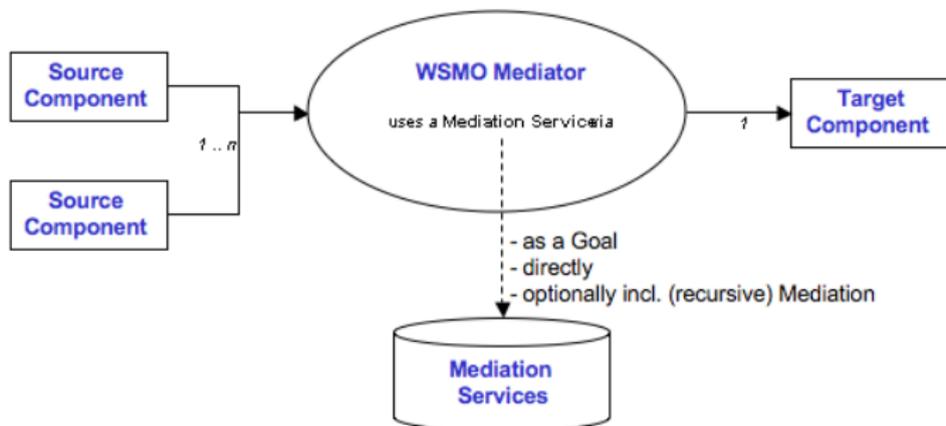
OOMediator: Define how concepts/relations can be mapped to another ontology. Mapping languages (under development) are basically powerful rule languages.

WGMediator: How can a service resolve a goal which does not “exactly” match? E.g. different interaction protocols require to split/merge messages, change order of messages, etc.

GGMediator: A goal can be a refinement of a more general goal, “Book a Trip” is more general than “Book a Flight”, etc

WSMO Mediators (2/2)

Properties:



SWSF

The Semantic Web Service Framework

<http://www.w3.org/Submission/SWSF/>

- ▶ Roots in OWL-S and PSL
- ▶ A first-order ontology for Semantic Web services, using the first-order notation of processes from PSL (ISO standard).
- ▶ remedies some weaknesses of OWL-S, by not being restricted to description logics.
- ▶ “grounding” problem not clearly addressed. No practical implementation efforts.
- ▶ also defines its own ontology and rule languages.

OWL-S, WSMO, SWSF

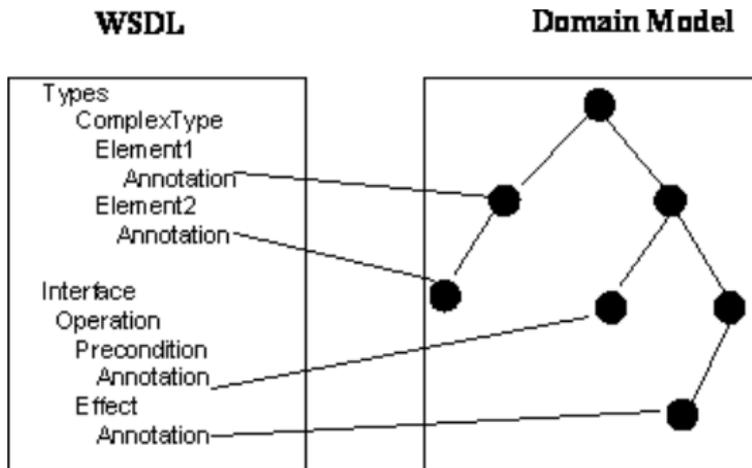
- ▶ “Heavy-weight” approaches
- ▶ Own languages, separate annotations
- ▶ still to a large extent research/academic (except big research projects with industry participation)
- ▶ not much emphasis so far to align with other WS-* standards (BPEL, WS-CDL, WS-Policy, WS-Security), except WSDL grounding.

A minimalistic approach: WSDL-S

- ▶ evolutionary and compatible upgrade of existing WS standards
- ▶ avoid duplication of what is already defined in WSDL
- ▶ minimal language commitment (OWL, UML, ? ...)
- ▶ Basically: embed what is needed from OWL-S profile directly in WSDL
- ▶ Why? Community is familiar with WSDL, provide a cautious extension.
- ▶ Claim: more practical approach for adoption

WSDL-S

<http://www.w3.org/Submission/WSDL-S/>



- ▶ define *service category*
- ▶ link operations to externally defined **operation ontology**
- ▶ link message types to externally defined concepts (e.g. defined in OWL)
- ▶ link operations to xternally defined **preconditions** and **effects**

No committment to formal language to be used, i.e. notions of match unclear.
For non-functional aspects, exploit existing WS-* standards. (not defined yet how),
e.g. "We are investigating how to represent QoS assertions using ontologies and rules
by extending the WS-Policy framework"

```

<?xml version="1.0" encoding="iso-8859-1"?>
<definitions name="PurchaseOrder"
targetNamespace="http://lstdis.cs.uga.edu/projects/meteor-s/wsd1-s/examples/purchaseOrder.wsdl"
xmlns="http://www.w3.org/2004/08/wsdl"
xmlns:tns="http://lstdis.cs.uga.edu/projects/meteor-s/wsd1-s/examples/purchaseOrder.wsdl"
xmlns:xs="http://www.w3.org/2001/XMLSchema"
xmlns:xsd1="http://lstdis.cs.uga.edu/projects/meteor-s/wsd1-s/examples/purchaseOrder.wsdl"
xmlns:wssem="http://lstdis.cs.uga.edu/projects/meteor-s/wsd1-s/examples/purchaseOrder.wsdl"
xmlns:POontology="http://lstdis.cs.uga.edu/projects/meteor-s/wsd1-s/ontologies/PurchaseOrder.owl"
xmlns:Rosetta="http://lstdis.cs.uga.edu/projects/meteor-s/wsd1-s/ontologies/rosetta.owl">
  <types>
    <xs:import namespace="http://lstdis.cs.uga.edu/projects/meteor-s/wsd1-s/examples/purchaseOrder.wsdl"
      schemaLocation="http://lstdis.cs.uga.edu/projects/meteor-s/wsd1-s/examples/WSSemantics.xsd"/>
    <xs:import namespace="http://lstdis.cs.uga.edu/projects/meteor-s/wsd1-s/examples/purchaseOrder.wsdl"
      schemaLocation="http://lstdis.cs.uga.edu/projects/meteor-s/wsd1-s/examples/POBilling.xsd" />
    <xs:import namespace="http://lstdis.cs.uga.edu/projects/meteor-s/wsd1-s/examples/purchaseOrder.wsdl"
      schemaLocation="http://lstdis.cs.uga.edu/projects/meteor-s/wsd1-s/examples/POItem.xsd" />
    <xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
      targetNamespace="http://lstdis.cs.uga.edu/projects/meteor-s/wsd1-s/examples/purchaseOrder.wsdl"
      xmlns="http://lstdis.cs.uga.edu/projects/meteor-s/wsd1-s/examples/purchaseOrder.wsdl">
      <!--Semantic annotations for these complex types are given in their respective type
      definitions -->
      <xs:complexType name="processPurchaseOrderRequest">
        <xs:all>
          <xs:element name="billingInfo" type="xsd1:POBilling"/>
          <xs:element name="orderItem" type="xsd1:POItem"/>
        </xs:all>
      </xs:complexType>
      <!--Semantic annotation is added directly to leaf element -->
      <xs:element name="processPurchaseOrderResponse" type="xs:string"
        wssem:modelReference="POontology#OrderConfirmation"/>
    </xs:schema>
  </types>
  <interface name="PurchaseOrder">
    <!--Category is added as an extensible element of an interface-->
    <wssem:category name="Electronics" taxonomyURI="http://www.naics.com/" taxonomyCode="443112" />
    <operation name="processPurchaseOrder" pattern="wsdl:in-out"
      wssem:modelReference="Rosetta:RequestPurchaseOrder" >
      <input messageLabel="processPurchaseOrderRequest"
        element="tns:processPurchaseOrderRequest"/>
      <output messageLabel="processPurchaseOrderResponse"
        element="processPurchaseOrderResponse"/>
    <!--Precondition and effect are added as extensible elements on an operation-->
    <wssem:precondition name="ExistingAcctPrecond"
      wssem:modelReference="POontology#AccountExists"/>
    <wssem:effect name="ItemReservedEffect"
      wssem:modelReference="POontology#ItemReserved"/>
    </operation>
  </interface>
</definitions>

```

Comparison: Coverage of basic representational aspects

1. *General service classifications*: common to all approaches
2. *pre- and postconditions*: common to all approaches
3. *behavior/protocol* description of the service OWL-S, WSMO, SWSF allow to encode complex behavior, WSDL-S implicit, or e.g. by embedding into BPEL4WS
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- ▶ Mediators: Own concept in WSMO, in OWL-S and SWSF not treated separately, but just as special kind of service.
 - ▶ Goal/requester view: Motivation to in WSMO separate concerns, goals/requests not treated in WSDL-S. Main issues:
 - ▶ How is a request/query to be formulated?
 - ▶ What are the related notions of “match”?
- a certain degree of language committment seems necessary

Standardization Activities

- ▶ W3C Semantic Annotations for WSDL Working Group
 - ▶ Charter currently being drafted
 - ▶ WSDL-S a likely starting point
- ▶ W3C SWS IG <http://www.w3.org/2005/09/sws-ig-charter>
- ▶ OASIS Semantic Web Services Architecture and Information Model

Issues/Connections

- ▶ No agreement yet in the community on formal underpinnings.
- ▶ Connections to multiple fields in AI:
 - ▶ Formal languages, reasoning (Description Logics Reasoning, Query Answering, Theorem Proving, Logic Programming)
 - ▶ Reasoning about processes, dynamics (bi-simulation, planning)
 - ▶ Multi-agent systems (probably similar conceptual frameworks, problems)
- ▶ Strong industry interest!

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You want to know more?

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Expectaciones:

- ▶ Motivación, para trabajar y aprender en un area desarrollando rapido (muchas especificaciones largos solo online, ...)
- ▶ Desafío: Cobinación de aspectos muy practicos con teoria y IA!
- ▶ SOAs son el futuro, hay mucho potencial!

Otros asignaturas

- ▶ Otoño: Axel Polleres, David Pearce “Métodos Avanzados de Razonamiento para Tecnologías del Conocimiento y Web Semántica”
- ▶ Primavera: Axel Polleres “Next Web Generation” (libre elección, en Inglés)

Thank you for your attention!