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
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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 possiblity to infer addidional knowledge

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

The RDF is the **data model** for the Semantic Web metadata. RDF describes a **labeled** graph of resources (nodes) linked to other resources or literals by predicates.

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<rdf:Description rdf:about="http://www.polleres.net/index.html">
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      <foaf:Name>Axel Polleres</foaf:Name>
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Resources identified by URIs, not necessarily only Web pages.

RDFS allows to define simple taxonomies on RDF vocabularies using `rdf:type`, `rdf:subClassOf`, `rdfs:subPropertyOf`

Some subtleties in RDF semantics (blank nodes, XML literals, RDF keywords treated as normal resources, reification, etc.)

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- 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.
Well, why is XML/XML Schema not enough? If everybody uses the same XML schema, then all is fine, right?

- RDF “flat” data model is easier to merge/combine than XML trees.
- OWL offers more expressivity, enables automatic inference.
- Still, only at the start so far, but first RDF/OWL vocabularies gain momentum: e.g. RSS, FOAF, Dublin Core, also iCAL has an RDF format which is widely used, etc.
- Take home message: OWL/RDF make it easy to combine these vocabularies and develop intelligent methods on top.
- Axiomatize meaning = semantics!
- Helps us to automatize aggregation and integration of data (not only) on the Web!
- Again: automatized reasoning and a bit of logic as the foundations!
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From static to dynamic

Current Web pages offer not only static data but also **dynamic services**, e.g. buying books, booking hotels, buying train tickets, etc.

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▶ **Just like data integration**, making applications and software components interoperable/combinable is not a new issue in the IT landscape...

http://www.renfe.es  

http://amazon.com
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▶ Question: Can we automatize service usage in a similar way as aggregation/querying of static data?
▶ Just like data integration, making applications and software components interoperable/combinable is not a new issue in the IT landscape... keyword: “Middleware”!
Current “buzzwords” on middleware are: Service-Oriented Architectures (SOA), Web Services.

Web services denote a set of standards to enable distributed application development based on Web standards.
Web Services (1/2)

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Four main “ingredients”:

- An agreed transport protocol (SOAP over HTTP)
- An agreed message description format (XML Schema, SOAP)
- A language for interface description (WSDL)
- A registry for publication and discovery of available services (UDDI)
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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)

What makes Web services different from its predecessors (CORBA, RMI, DCOM, etc.)?
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- extensible (e.g. by Semantic Web technology), rely on open standards
- 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)

1. Define message types by XML Schema
2. Define messages and operations
3. Group several operations in "ports"
4. Define binding protocol (e.g. SOAP over HTTP, HTTP/GET, etc.)
5. Define the service endpoint address where the service can be invoked.
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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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<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" />
   </wsdl:operation>
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</wsdl:portType>

<wsdl:binding name="GlobalWeatherSoap" type="tns:GlobalWeather">
   <soap:binding transport="http://schemas.xmlsoap.org/soap/http" style="document" />
   <wsdl:operation name="GetWeather">
     <wsdl:input><soap:body use="literal" /></wsdl:input>
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Web Services - UDDI

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- an API for publishing and searching Business partners and service providers.
- a data model for service and business entities
- allows to link to service classifications (e.g. UNSPC) and technical information (e.g. provided Web services)

However: general classifications or keywords in natural language description are insufficient for automatic discovery.

Summary: WSDL, SOAP, UDDI operate on a largely “syntactic” level. Would make sense to use the similar metadata format, for annotating services, WSDL operations, input/output messages, etc. to describe their meaning.
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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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- Semantically enhanced repositories
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- Tools and platforms that semantically enrich current Web service descriptions and facilitate:
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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?)
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Approaches:

- OWL-S
- WSMO
- SWSF
- WSDL-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:

- Resource
- ServiceProfile: What the service does...
- ServiceModel: How it works...
- ServiceGrounding: How to access it...
- Service: provides
- presents
- describedBy
- supports
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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▶ Advertisements of Web Services capabilities (non-functional properties, QoS, Description, classification, etc.)
▶ Request of Web services with a given set of capabilities

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)
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

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)

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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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

- Provide the formally specified terminology of the information used by all other components
- Connectors between components with mediation facilities for handling heterogeneities

Goals

Ontologies

Web Services

Mediators

Semantic description of Web Services
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
WSMO services/goals

Define the provided/requested:

▶ capability
▶ interfaces

**Capability:** comparable to OWL-S profile

**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)
WSMO services/goals

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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.
Properties:
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 committment (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 externally defined preconditions and effects

No commitment 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://lsdis.cs.uga.edu/projects/meteor-s/wsdl-s/examples/purchaseOrder.wsdl"
  xmlns:tns="http://www.w3.org/2004/08/wsdl"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema"
  xsi:schemaLocation="http://www.w3.org/2001/XMLSchema"
  xmlns:wssem="http://lsdis.cs.uga.edu/projects/meteor-s/wsdl-s/examples/purchaseOrder.wsdl"/>
<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>
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
4. non-functional aspects (QoS, cost, availability, etc.) OWL-S, WSMO, SWSF provide extensible sets of non-functional properties, WSDL-S sees this out of scope
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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!
Summary

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You want to know more?
Outlook

- You want about how methodology/methods from your course can be deployed here?
- Discuss concrete use cases?
- Investigate WS-* standards in detail?
- Get your hands dirty in programming WS? ;-)
- Help in developing intelligent Web, intelligent Web Services?
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Posibilidades:
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▶ Becas para proyectos concretos posible
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Expectaciones:

- Motivación, para trabajar y aprender en un área desarrollando rápido (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!