UNIVERSIDADE FEDERAL
DE SANTA CATARINA

Semantic Web Services

SBBD 2008

Renato Fileto
Frank Siqueira

Collaborators (SWS tools selection):
Giorgio Merize
Rodrigo Zeferino

{fileto|frank|giorgio|rodrigo.zeferino}@inf.ufsc.br
INE/CTC/UFSC

Topics

- **Introduction**
- **Web Services (WS)**
- **Semantic Web (SW)**
- **Semantic Web Services (SWS)**
- **Some Major Efforts towards SWS**
  - WSDL-S
  - OWL-S
  - SWSF (SWSO + SWSL)
  - WSMO (WSMO + WSML + WSMX)
- **Software Tools:** WSMT, WSMX, IRS-III, ...
- **Case study: Travelling to SBBD**

Introduction

Web Services Technology
(discovery, selection, composition, and web-based execution of services)
+
Semantic Web
(ontologies and machine supported data interpretation)
=
Semantic Web Services
(integrated solution for realizing the vision of the next generation of the Web)

The Web

- The Web was initially designed for application to human interactions
- Served very well its purpose:
  - Information sharing: a distributed content library.
  - Enabled B2C e-commerce.
  - Non-automated B2B interactions.
- How did it happen?
  - Built on standards: HTTP, HTML, URI, ...
  - Very few assumptions made about computing platforms.
  - Ubiquity.

What's next?

- The Web is everywhere. There is a lot more we can do!
  - E-marketplaces.
  - Open, automated B2B e-commerce.
  - Business process integration on the Web.
  - Resource sharing, distributed computing.
- Current approach is *ad-hoc* on top of existing standards.
  - e.g., application-to-application interactions with HTML forms.
- **Goal:** enabling systematic and automated application-to-application interaction on the Web.

W3C´s Protocol Working Group

"...the Web can grow significantly in power and scope if it is extended to support [automated] communication between applications, from one program to another."

W3C's Protocol Woking Group

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- **Semantic Web Services (SWS)**
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- **Case study: Travelling to SBBD**

Web Services

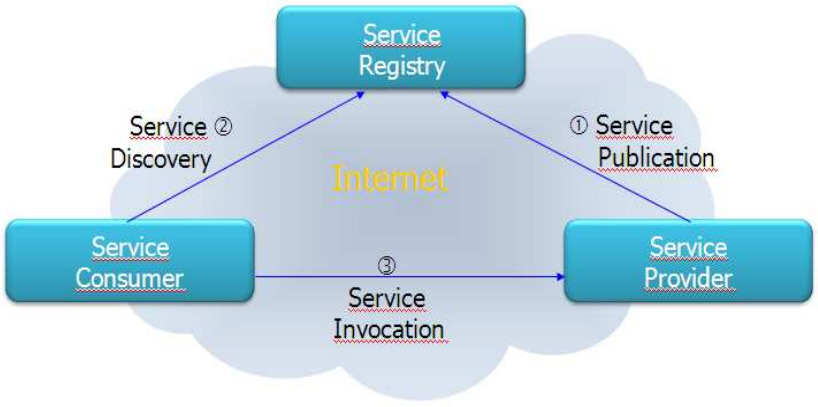
- Encapsulated, loosely coupled Web “components” that can bind dynamically to each other.
- Services are programmatically accessible over standard Internet protocols

A Web Service

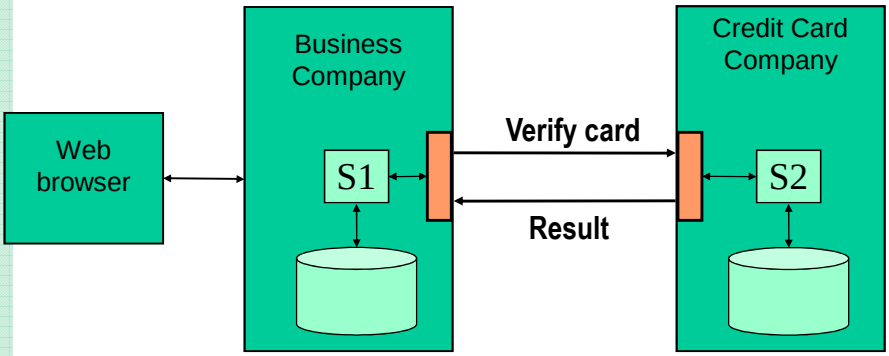
- Identified by an URI
- Self-describing and openly accessible
- Can be remotely invoked through a well-defined interface
- Exchanges data in XML format
- Interacts with applications and other services via messages exchange (HTTP/SMTP)
- Independent from other services and applications, but can cooperate with them

Web Service Architecture

Based on the Service Oriented Architecture (SOA)



Example



- Obviously, there are other technologies for doing this
- Web services standardize connections, enabling "*plug and play*" on the Web.

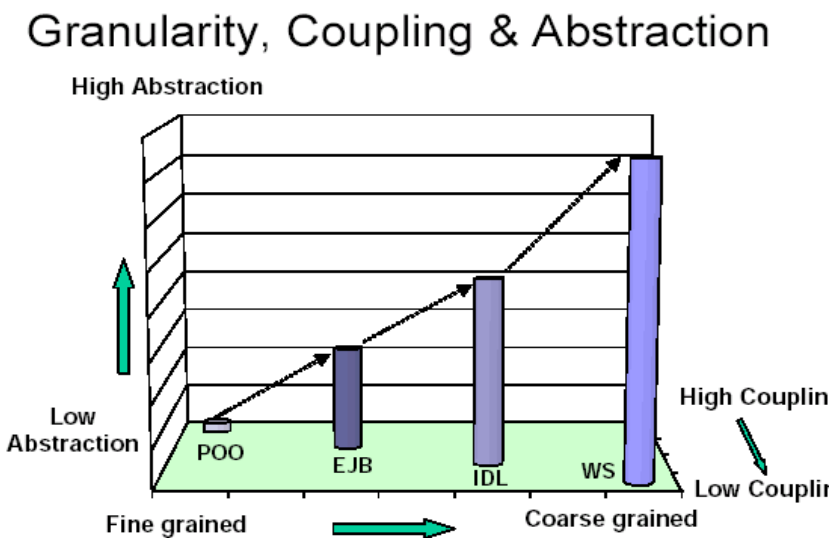
Web Service Objectives

- Universal interoperability
- Exploit ubiquity of the Web
- Enable dynamic binding
- Efficiently support open environment (Web) and more restrict environments if necessary
- Minimize incompatibility costs
  - programming languages,
  - operating systems,
  - network protocols.
- **An effort towards building a distributed computing platform on the Web.**

Why Web Services?

- Based on generally accepted standards
- Require little additional infrastructure
- Loose coupling
- Focus in messages and documents, not *APIs*
- Easy to use
- Complement existing technologies
- Interoperability
- Everybody use, have plans to use or is forced to use

Technology Evolution



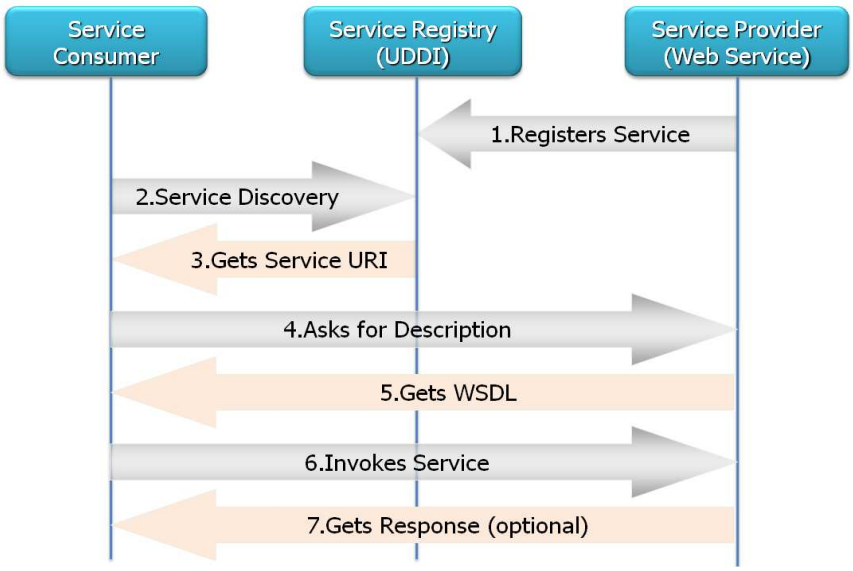
Web Services Framework

- What goes "on the wire":
  Formats and protocols.
- What describes what goes on the wire:
  Description languages.
- How to find the services we need:
  Discovery and selection of services.
- How to assemble and control the execution of services in processes on the Web:
  Composition of services.

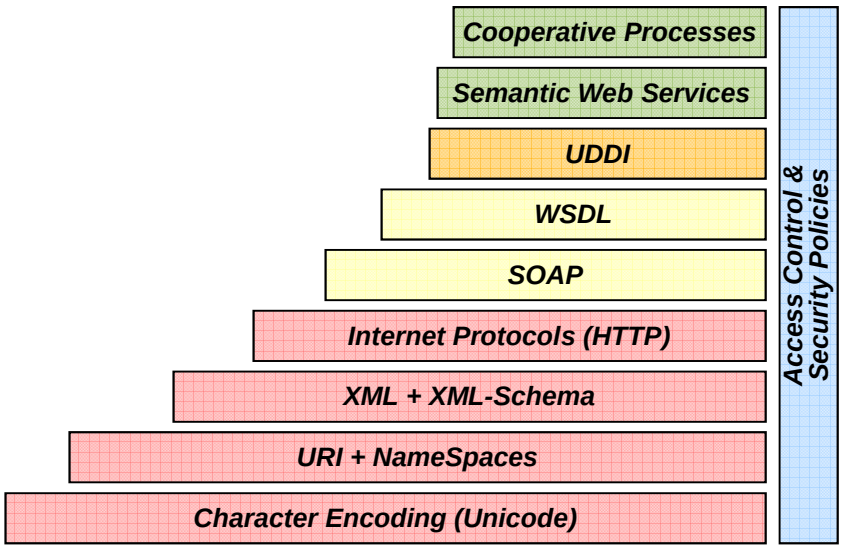
Current Web Services Technologies

- Standards for publication, invocation & search
  - *Unicode, URI + namespaces*
  - *XML (eXtensible Markup Language) + XML-Schema*
  - *SOAP (f.k.a. Simple Object Access Protocol)*
  - *WSDL (Web Services Definition Language)*
  - *UDDI (Unified Data Description and Interchange)*
- Implementation technologies
  - *.NET (Microsoft)*
  - *Java Technology for Web Services (SUN)*
  - *... and many others.*

Web Service Interaction



Current Web Services Standards



Characters Encoding

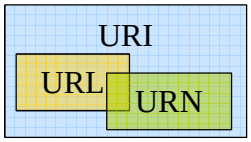
- <?xml encoding='UTF-8'?>
- <?xml encoding='UTF-16'?>
- <?xml encoding='EUC-JP'?>
- <?xml version="1.0" encoding='ISO-8859-1'?>

URI (Uniform Resource Identifier)

An URI identifies an abstract or physical resource

URNs (Uniform Resource Names)

URLs (Uniform Resource Locators)



Examples:

ftp://ftp.is.co.za/rfc/rfc1808.txt
http://www.ietf.org/rfc/rfc2396.txt
mailto:John.Doe@example.com
news:comp.infosystems.www.servers.unix
ldap://[2001:db8::7]/c=GB?objectClass?one
telnet://192.0.2.16:80/
tel: +1-816-555-1212

NameSpaces

- **<x xmlns:edi="http://ecommerce.org/schema">**
  <!-- *the "edi" prefix is bound to http://ecommerce.org/schema for the "x" element and contents* -->
  </x>

- <book **xmlns="**urn:loc.gov:books"
  xmlns:isbn="urn:ISBN:0-395-36341-6">
  <title>Cheaper by the Dozen**</title>**
  <isbn:number>1568491379**</isbn:number>**
  </book>

- <schema **xmlns:"**http://www.w3.org/2001/XMLSchema">
  :
  <schema>

XML – eXtensible Makup Language

<?xml version=”1.0”?> <!DOCTYPE people SYSTEM
”http://www.wsmo.org/workinggroup.dtd”>
<!−− This XML document gives information about working group members of the WSMO working group −−>
<people xmlns=”http://www.wsmo.org/namespace”>
< title >WSMO working group members</title>
<member chair=”yes”>
<firstname>Dieter</firstname><lastname>Fensel</lastname>
< affiliation >DERI International</ affiliation >
</member>
<member chair=”yes”>
<firstname>John</firstname><lastname>Domingue</lastname>
< affiliation >Open University</ affiliation >
</member>
<member>
<firstname>Axel</firstname><lastname>Polleres</lastname>
< affiliation >Univ. Rey Juan Carlos</ affiliation >
</member>
:
</people>

DTD

```
<!DOCTYPE people [
 <!ELEMENT people (title,member+)>
 <!ELEMENT member (firstname,lastname,affiliation+)>
 <!ATTLIST member chair (yes|no) ”no”>
 <!ELEMENT title (#PCDATA)>
 <!ELEMENT firstname (\#PCDATA)>
 <!ELEMENT lastname (\#PCDATA)>
 <!ELEMENT affiliation (\#PCDATA)>
]>
```

XML-Schema

An *XML-Schema* document describes

- elements,
- attributes,
- relationships,
- etc.

that can be used in one or more XML documents, i.e., defines a class of XML documents that follow a set of structural and data constraints

- *XML-Schema* uses the *XML* syntax
- *XML-Schema* is more robust, versatile and powerful than *DTD* (*Document Type Definition*)

XML-Schema (example)

```
<XML version =”1.0” encoding=”UTF−8”?>
 <xs:schema
  xmlns=”http://www.wsmo.org/namespace”
  xmlns:xs=”http://www.w3.org/2001/XMLSchema”
  elementFormDefault=”qualified” attributeFormDefault=”qualified”
  targetNamespace=”http://www.wsmo.org/namespace” >
   <xs:element name=”people”>
       <xs:complexType>
          <xs:sequence>
              <xs:element name=”title” type=”xs:string” maxOccurs=”1”/>
              <xs:element name=”member” type=”person” maxOccurs=”unbounded”/>
          </xs:sequence>
       </xs:complexType>
   </xs:element>

 :
 </xs:schema>
```

XML-Schema (example cont)

```
<xs:complexType name=”person”>
  <xs:sequence>
     <xs:element name=”firstname” type=”namestring” minOccurs=”1” maxOccurs=”2”/>
     <xs:element name=”lastname” type=”namestring” minOccurs=”1” maxOccurs=”2”/>
     <xs:element name=”affiliation” type=”namestring” maxOccurs=”unbounded”/>
  </xs:sequence>
  < xs:attribute name=”chair” default=”no”>
     <xs:simpleType>
        < xs:restriction base=” xs:string ”>
           <xs:enumeration value=”yes”/>
           <xs:enumeration value=”no”/>
        </ xs:restriction >
     </xs:simpleType>
  </ xs:attribute >
</xs:complexType>
```

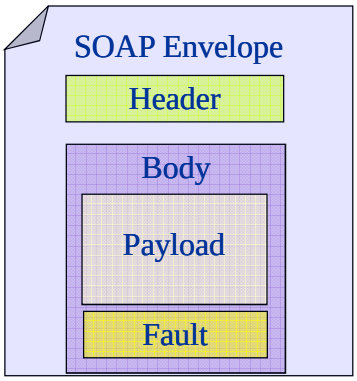
XML-Schema (example cont)

```
<xs:simpleType name=”namestring”>
    < xs:restriction base=” xs:string”>
        <!−− This pattern says that names are strings
             starting with an uppercase letter −−>
        <xs:pattern value=”\{p}\{Lu\}.\∗”/>
    </ xs:restriction >
</xs:simpleType>
```

Validating XML Documents

- **Well-formed document**: satisfies the restrictions expressed in the XML specification (http://www.w3.org/TR/2004/REC-xml-20040204)
- **Valid document**: satisfies the restrictions expressed in a schema specification (valid elements, attributes, nesting, etc.) written in DTD or XSL associated to the XML document

SOAP



SOAP

- Request example

```
<?xml version="1.0" encoding="UTF-8"?>
<S:Envelope
    xmlns:S="http://schemas.xmlsoap.org/soap/envelope/">
<S:Header/>
<S:Body
    xmlns:ns1="http://ufsc.br/previsao">
  <ns1:getMinTemperature>
    <location>Florianópolis<location>
  </ns1:getMinTemperature>
</S:Body>
</S:Envelope>
```

SOAP

- Return example

```
<?xml version="1.0" encoding="UTF-8"?>
<S:Envelope
xmlns:S="http://schemas.xmlsoap.org/soap/envelope/">
<S:Body>
   <ns1:getMinTemperatureResponse
    xmlns:ns1="http://ufsc.br/previsao">
      <return>13.2</return>
   </ns1:getMinTemperatureResponse>
</S:Body>
</S:Envelope>
```

SOAP + attachments

```
MIME-Version: 1.0
Content-Type: Multipart/Related; boundary=MIME_boundary;
type=text/xml;
start="<soapmsg.xml@example.com>“
--MIME_boundary
Content-Type: text/xml; charset=UTF-8
Content-Transfer-Encoding: 8bit
Content-ID: soapmsg.xml@example.com
<SOAP-ENV:Envelope xmlns:SOAP-ENV=“http://schemas.xmlsoap.org/soap/envelope/">
 <SOAP-ENV:Body>
      ..
      <Person>
          <Picture href=“http://example.com/myPict.jpg” />
      </Person>
      ..
 </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
--MIME_boundary--
```

WSDL - Web Services Description Language

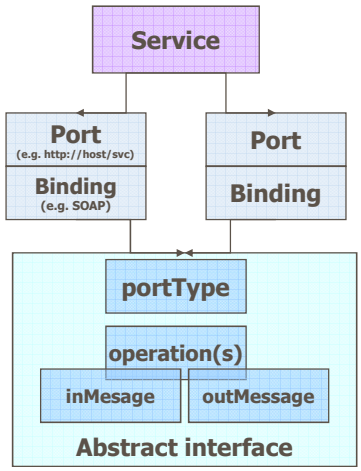
- Language for describing Web services
  - W3C Standard
  - XML based
  - Describes the interface of a Web service
  - Equivalent to Corba IDL description
  - Platform independent description
  - Extensible language
  - A *de facto* industry standard.

Using WSDL

- Allows tools to generate compatible client and server stubs.
- Allows industries to define standardized service interfaces.
- Allows advertisement of service descriptions, enabling dynamic discovery and binding of compatible services.
- Provides a normalized description of heterogeneous applications.

WSDL Structure

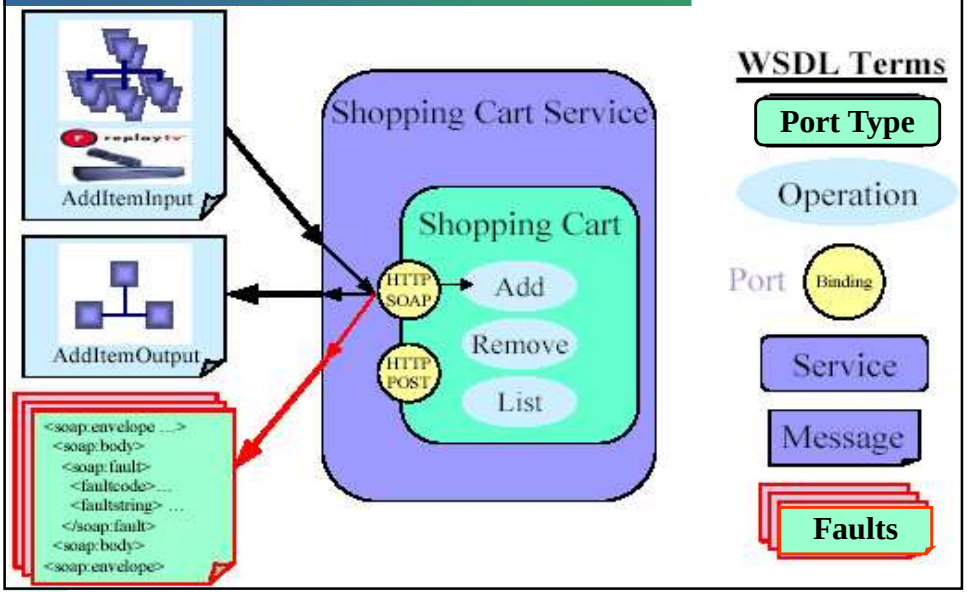
- portType
  - Abstract definition of a service (set of operations)
- Multiple bindings per portType:
  - How to access it
  - SOAP, JMS, direct call
- Ports
  - Where to access it



WSDL elements

- ***Types:*** type definitions using *XML-Schema*
- ***Messages:*** describes what goes on the data flows, using the the types defined using *XML-Schema*
- ***Port types:*** colections of related operations, using messages to exchange arguments and results
- ***Bindings:*** associate port types with protocolos (e.g., HTTP GET/POST) and data formats
- ***Ports:*** associate bindings with network addresses
- ***Services:*** collection of related ports

Example: Shopping Cart



WSDL definitions

```
<definitions name="ShoppingCartDefinitions"
    targetNamespace="http://example.com/ShoppingCart.wsdl"
    xmlns:tns="http://example.com/ShoppingCart.wsdl"
    xmlns:xsd1="http://example.com/ShoppingCart.xsd"
    xmlns:soap="http://schemas.xmlsoap.org/wsdl/soap/"
    xmlns="http://schemas.xmlsoap.org/wsdl/>
```

A WSDL document

```
<definitions name="ShoppingCartDefinitions"
        xmlns="http://schemas/xmlsoap.org/wsdl"
        targetNamespace="http://example.com/ShoppingCart.wsdl" … >
 <types> … </types>
 <message name="AddItemInput"> … </message>
 <message name="AddItemOutput"> … </message>
 <portType name="ShoppingCart"> … </portType>
 <binding name="CartHTTPXMLBinding" type="tns:ShoppingCart">…
 <binding name="CartSOAPBinding" type="tns:ShoppingCart">…
 <service name="ShoppingCartService">
      <port name="HTTPXMLCart" binding="tns:CartHTTPXMLBinding">
      …
      <port name="SOAPCart" binding="tns:CartSOAPBinding"> …
 </service>
 <import namespace="…" location="…">
</definitions>
```

Types

```
<types>
 <schema
     targetNamespace="http://myservice.net/carttypes"
     xmlns="http://www.w3.org/2000/10/XMLSchema">
     <complexType name="item"><all>
         <element name="description" type="xsd:string"/>
         <element name="quantity" type="xsd:integer"/>
         <element name="price" type="xsd:float"/>
     </all></complexType>
 </schema>
</types>
```

Messages

```
<message name="AddItemInput">
  <part name="cart-id" type="xsd:string"/>
  <part name="item" type="carttypes:item"/>
  <part name="image" type="xsd:base64Binary"/>
</message>
```

Port Types

```
<portType name="ShoppingCart">
  <operation name="AddItem">
      <input message="tns:AddItemInput"/>
      <output message="tns:ACK"/>
      <fault name="BadCartID" message="tns:BadCartID"/>
      <fault name="ServiceDown" message="tns:ServiceDown"/>
  </operation>
  <operation name="RemoveItem"> … </operation>
  <operation name="ListItems"> … </operation>
</portType>
```

SOAP Binding

```
<binding name="CartHTTPSOAPBinding" type="tns:ShoppingCart">
<soap:binding style="RPC" transport="http://schemas.xmlsoap.org/soap/http"/>
<operation name="AddItem">
    <soap:operation soapAction="http://myservice.net/cart/AddItem"/>
    <input>
        <soap:body use="encoded" namespace="http://myservice.net/cart"
          encodingStyle="http://schemas.xmlsoap.org/soap/encoding"/>
    </input>
    <output>
        <soap:body use="encoded" namespace="http://myservice.net/cart"
          encodingStyle="http://schemas.xmlsoap.org/soap/encoding"/>
    </output>
    <fault name="BadCartID"> <soap:body use="encoded" namespace= … /></fault>
    <fault name="ServiceDown"> <soap:body use= … /> </fault>
</operation> …
</binding>
```

HTTP Binding

```
<binding name="CartHTTPPostBinding" type="tns:ShoppingCart">
<http:binding verb="POST"/>
<operation name="AddItem">
 <http:operation location="/AddItem"/>
 <input>
      <mime:content type="application/x-www-form-urlencoded"/>
 </input>
 <output>
      <mime:content type="application/x-www-form-urlencoded"/>
 </output>
 <fault name="BadCartID"> <mime:mimeXML/> </fault>
 <fault name="ServiceDown"> <mime … /> </fault>
</operation> …
</binding>
```

Ports

```
<port name="SOAPCart" binding="tns:SOAPCartBinding">
  <soap:address location="http://myservice.net/soap/cart"/>
</port>
<port name="HTTPPostCart" binding="tns:HTTPPostCartBinding">
  <http:address location="http://myservice.net/cart"/>
</port>
```

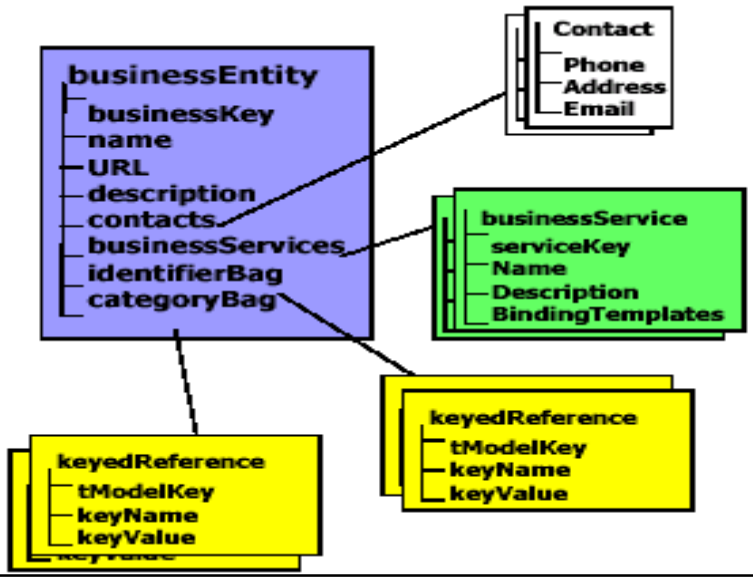
Services

```
<service name="ShoppingCartService">
  <documentation>A Shopping Cart for the Web</documentation>
  <port name="HTTPPostCart" binding="tns:HTTPPostCartBinding">
      <http:address location="http://myservice.net/cart"/>
  </port>
  <port name="SOAPCart" binding="tns:SOAPCartBinding">
      <soap:address location="http://myservice.net/soap/cart"/>
  </port>
</service>
```

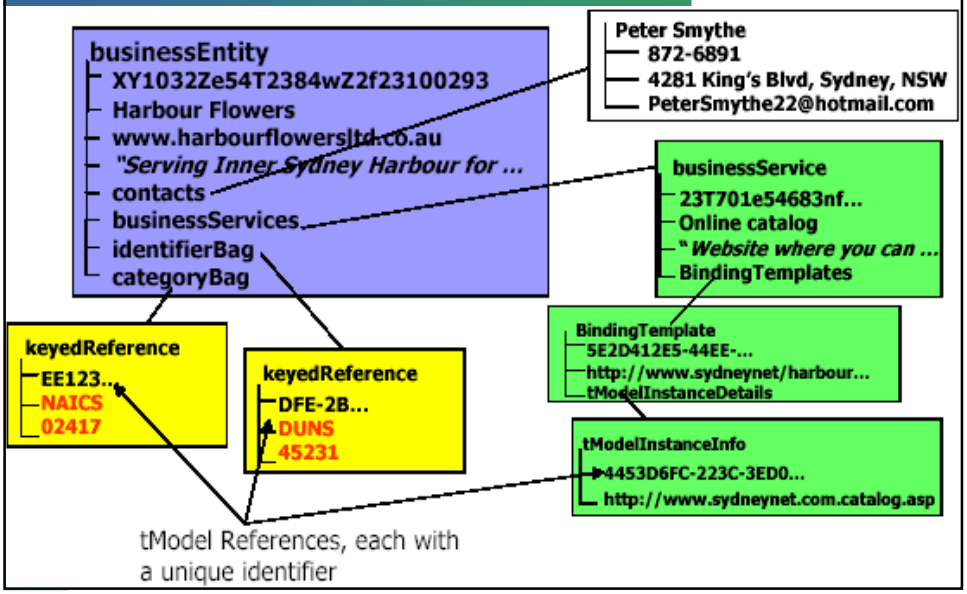
UDDI

- Defines the operation of a service registry:
  - Data structures for registering
    - Businesses
    - Technical specifications: tModel is a keyed reference to a technical specification.
    - Service and service endpoints: referencing the supported tModels
  - SOAP Access API
  - Rules for the operation of a global registry
    - "private" UDDI nodes are likely to appear, though.

UDDI Basic Structure



References to Taxonomies



API SOAP para o *UDDI*

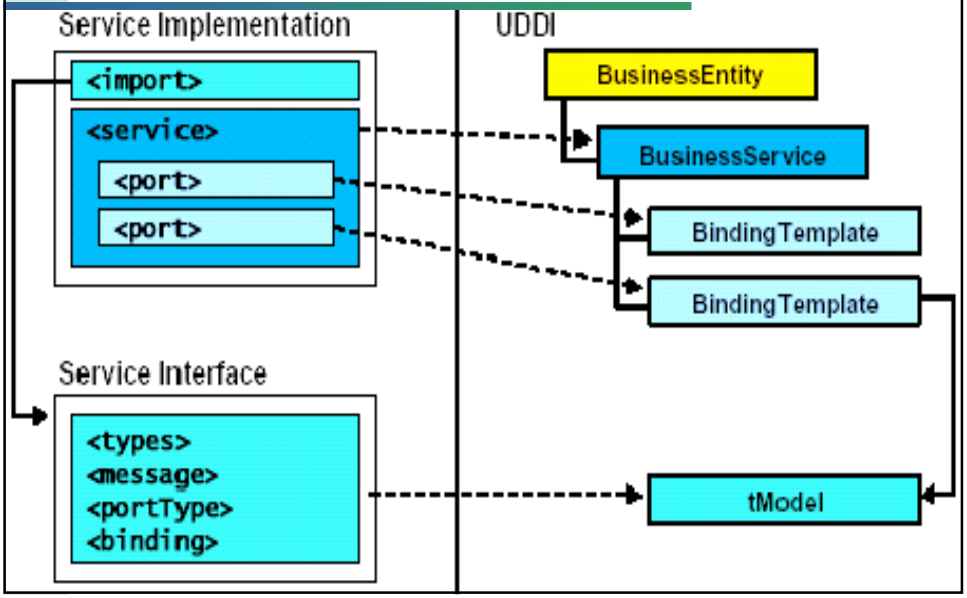
***API* de consulta**

- Busca
  - *find_business*
  - *find_service*
  - *find_binding*
  - *find_tModel*
- *Consulta a detalhes*
  - *get_businessDetail*
  - *get_serviceDetail*
  - *get_bindingDetail*
  - *get_tModelDetail*

***API* de publicação**

- *Adição*
  - *save_business*
  - *save_service*
  - *save_binding*
  - *save_tModel*
- *Remoção*
  - *delete_business*
  - *delete_service*
  - *delete_binding*
  - *delete_tModel*
- *Segurança*
  - *get_authToken*
  - *discard_authToken*

Mapeamento *WSDL - UDDI*



Major Challenges in Web Services

- ***Discovery*:** find available resource in the Web to meet specific needs
- ***Selection*:** choose the most suitable resources, by several criteria (e.g., cost, matching interfaces)
- ***Composition*:** design, enact and synchronize ("choreograph") distributed processes on the Web, using Web services as basic building blocks

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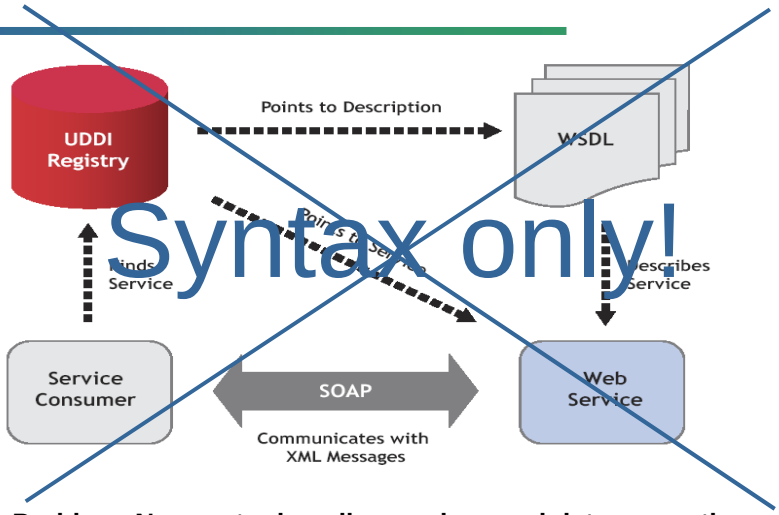
- **Software Tools:** WSMT, WSMX, IRS-III, ...
- **Case study: Travelling to SBBD**

WS standards lack of semantics!



Problem: No way to describe services and data semantics for machine processing in order to support automated service discovery, selection, composition, ...

Deficiencies of WS Technology

- Only **syntactical** information descriptions and syntactic support for discovery, composition and execution

=> Web Service reuse and integration needs to be done manually

- **No semantic markup** for contents / services

=> Current Web Service Technology Stack failed to realize the promise of Web Services

The Sematic Web

"The Semantic Web is an extension of the current Web in which information is given well-defined meaning, better enabling computers and people to work in cooperation."

Tim Berners-Lee, James Hendler, Ora Lassila,
The Semantic Web, Scientific American, May 2001

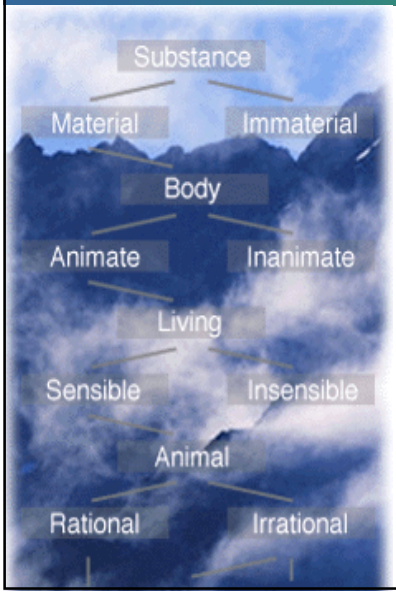
Means:

- **Standards for representing data and metadata**
- **Semantic descriptions attached to data and services**
- **Reasoning (e.g., inference) based on semantic descriptions**

Ontology in Philosophy

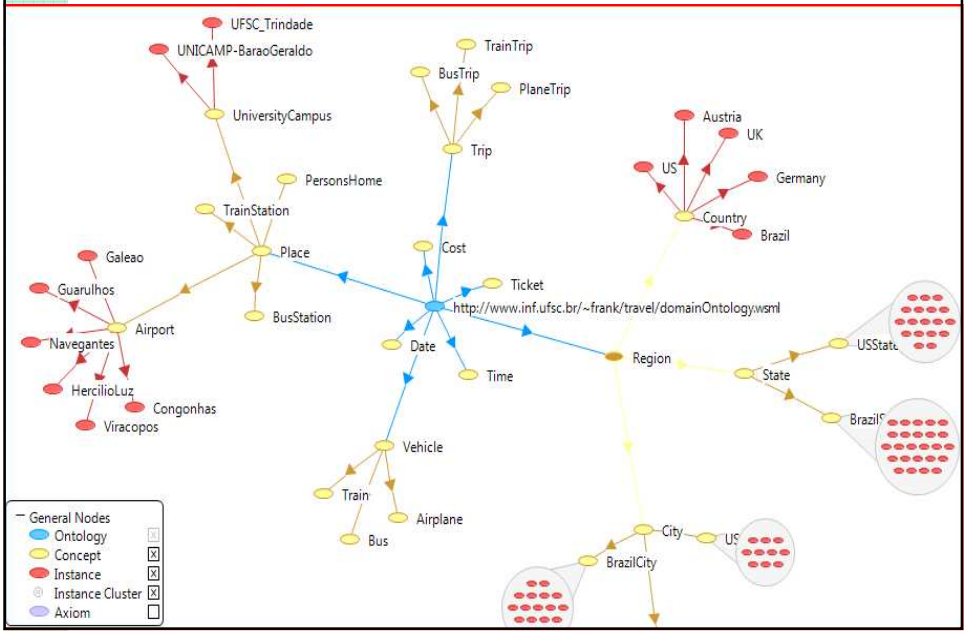
- **From Greek:**
  Ontos = being, logos = science
- **Shared understanding** of some domain of interest which
- Conceived as a **set of concepts** (e.g. entities, attributes, processes), their **definitions** and **inter-relationships**.
- Referred to as a **conceptualization**.
- May be used as a **unifying framework** to solve the above problems in the above described manner.
- Entails some sort of **world view [with respect to a given domain]**.

Ontologies in Computer Science



- **Shared conceptualizations** of a domain
- **Explicit** and **Formal** to enable its use by machines
- Can have different forms:
  - **Thesaurus** with the semantic relationships between terms (e.g., synonym, holonym (IS_A), meronym (PART_OF))
  - **Taxonomy**
  - **Class Diagram**
  - **Knowledge Base**
    - Classes, properties and their relationships
    - Instances of classes

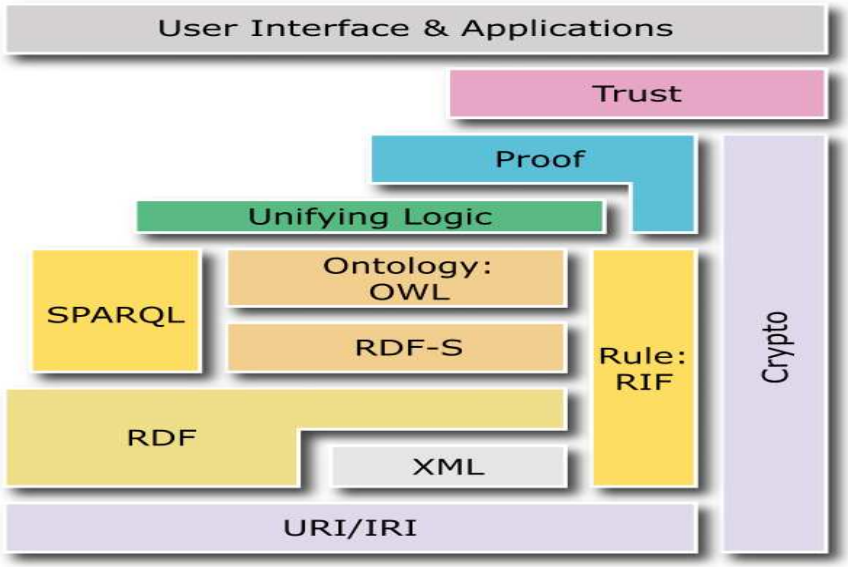
Ontology Example – Trip



Applications

- **Accurate search of resources**
  Ex.: Student(Mary), Model(Mary), Saint(Mary)
- **Interoperability**
- **Intelligent agents**
- **Reuse and composition of resources**
- **Semantically enabled services & workflows**
  :

Semantic Web Standards (2006)



Semantic Heterogeneity in XML

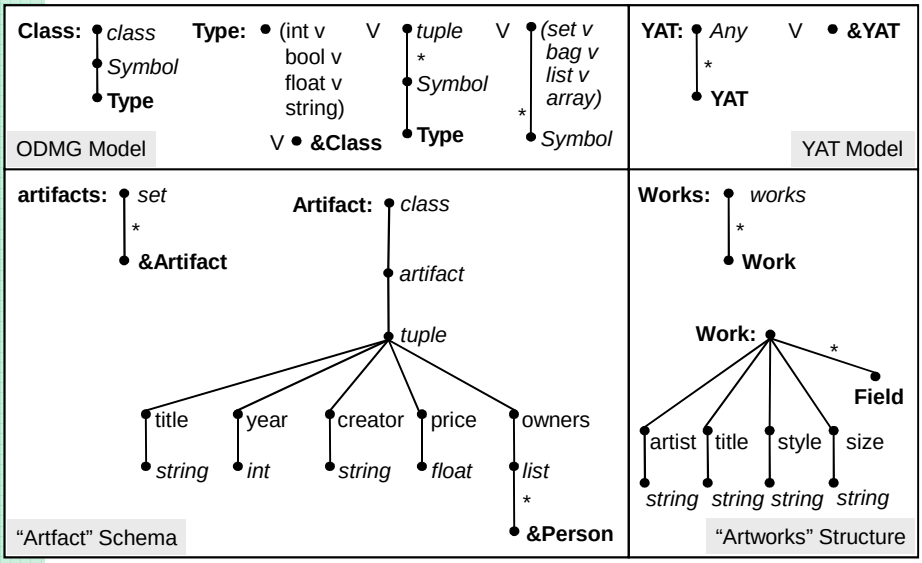
```
<object id="a1" class="artifact">
<tuple>
    <title> Nympheas </title>
    <year> 1897 </year>
    <creator> Monet </creator>
    <price> 10,000,000 </price>
    <owners refs="p1,p2,p3">
</tuple>
</object>

<object id="p3" class="person">
<tuple>
    <name> Claudia </name>
    <age> 17 </age>
</tuple>
</object>
```

```
<work>
<artist> Monet </artist>
<name> Nympheas </name>
<style> Impressionist </style>
<size> 21 x 61 </size>
<cplace> Givern </cplace>
</work>

<work>
<artist> Monet </artist>
<title> Waterloo Bridge </title>
<style> Impressionist </style>
<size> 29.2 x 46.4 </size>
<history>
    Painted with
    <tech> Oil on canvas </tech>
    in ...
</history>
</work>
```

XML as a Standard Data Model



RDF – Resource Description Framework

A standard language & model for expressing semantics on the Semantic Web.

An **RDF statement** is a triple of the form:

- **Resource**: anything that has a URL
- **Property**: any property of the resource
- **Value**: a literal or another resource

RDF-Schema defines the classes of resources, the possible properties for each class of resource, and the possible values for these properties.

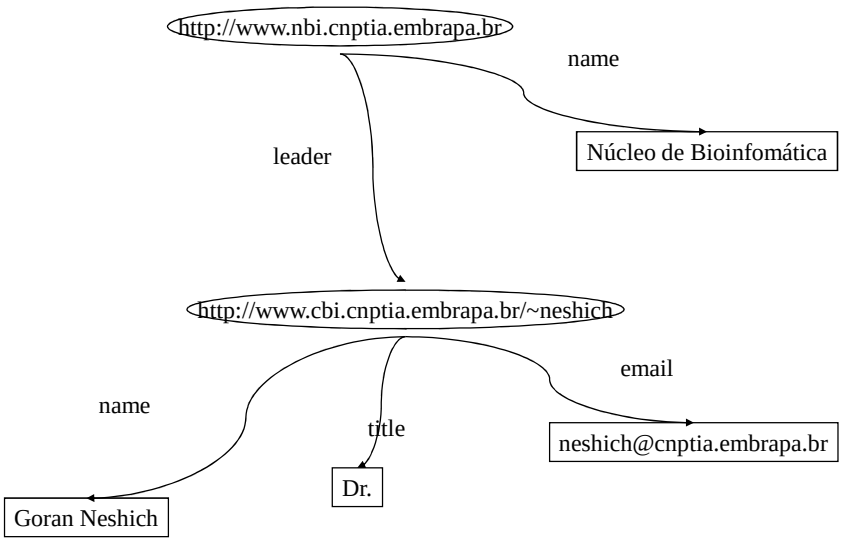
The proposed **standard formats for representing ontologies on the Semantic Web** (e.g., DAML+OIL, OWL) are **extensions of RDF**.

RDF's XML Syntax

```
<?xml version="1.0"?>
<rdf:RDF   xmlns:RDF "http://www.w3.org/RDF/RDF/"
           xmlns:dc "http://dublincore.org/dc">
<rdf:Description about="http://www.nbi.cnptia.embrapa.br">
    <dc:name> Núcleo de Bioinfomática </dc:name>
    <leader>
      rdf:resource="http://www.cbi.cnptia.embrapa.br/~neshich"
    </leader>
</rdf:Description>

<rdf:Description
    about="http://www.nbi.cnptia.embrapa.br/~neshich">
 <dc:name> Goran Neshich  </dc:name>
 <title> Dr. </title>
 <dc:email> neshich@cnptia.embrapa.br </dc:email>
</rdf:Description>
</rdf:RDF >
```

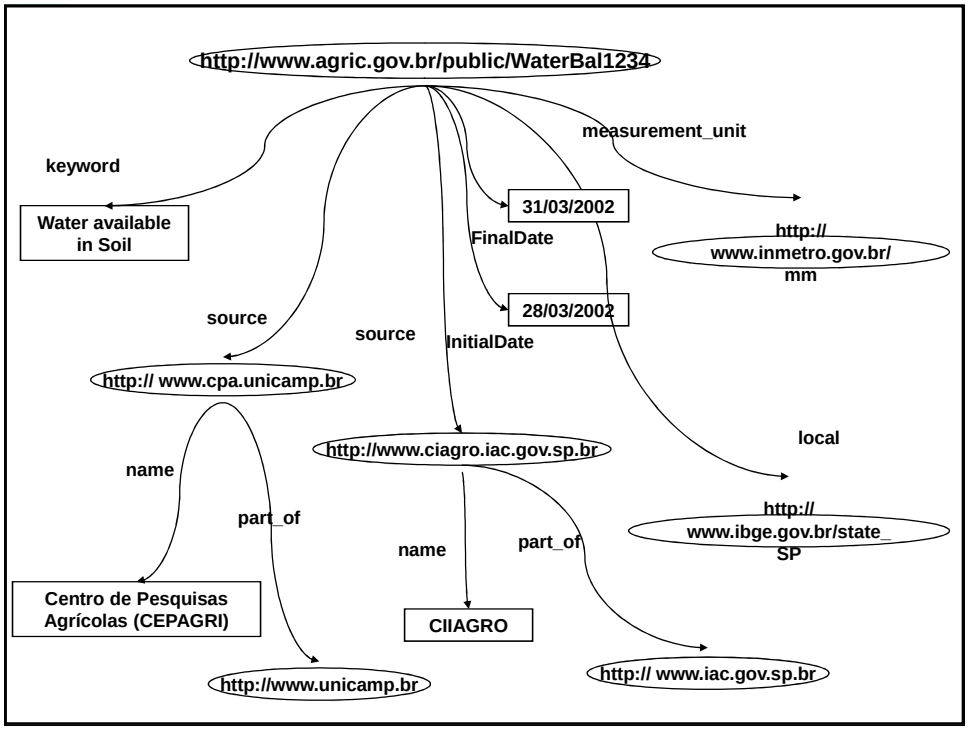
RDF graph-like structure



Metadata in RDF

Water Balance (same place and institution)

```
<?xml version="1.0"?>
<rdf:RDF   xmlns:RDF "http://www.w3.org/RDF/RDF/“
           xmlns "http://agric.gov.br/DocStd/“>
<rdf:Description about="http://www.agric.gov.br/public/WaterBal1234">
       <Source>
       rdf:resource=“http://www.cepagri.unicamp.br”
       rdf:resource=“http://www.ciagro.iac.gov.sp.br”
   <Source>
       <InitialDate> 28/03/2002 </InitialDate>
   <FinalDate> 31/03/2002 </FinalDate>
       <keyword> Water available in Soil </keywork>
   <local>
       rdf:resource= “http://www.ibge.gov.br/state_SP”
   </local>
       <measument_unit>
       rdf:resource= “http://www.inmetro.gov.br/mm”
   </measument_unit>
</rdf:Description>
</rdf:RDF>
```



RDF-Schema

```
<rdf:about="&AgricZoning;Country" rdfs:label="Country">
   <rdfs:subClassOf df:resource="&AgricZoning;TerritorialDivision"/>

<rdf:about="&AgricZoning;State" rdfs:label="State">
   <rdfs:subClassOf df:resource="&AgricZoning;TerritorialDivision"/>

<rdf:Property rdf:about="&AgricZoning;statesOfCountry"
    a:minCardinality="1"
    rdfs:label="statesOfCountry">
   <rdfs:domain rdf:resource="&AgricZoning;Country"/>
   <rdfs:range rdf:resource="&AgricZoning;State"/>
   <a:inverseProperty rdf:resource="&AgricZoning;countryOfState"/>
</rdf:Property>
```

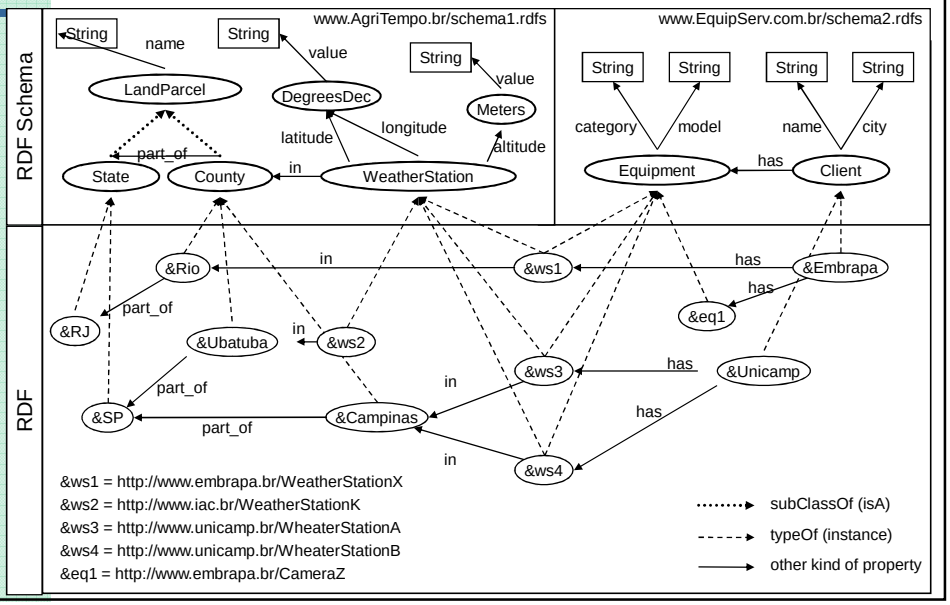
RDF-Schema

```
<rdf:Property rdf:about="&AgricZoning;countryOfState"
    a:maxCardinality="1"
    a:minCardinality="1"
    rdfs:label="countryOfState">
   <rdfs:range rdf:resource="&AgricZoning;Country"/>
   <rdfs:domain rdf:resource="&AgricZoning;State"/>
   <a:inverseProperty
  rdf:resource="&AgricZoning;statesOfCountry"/>
</rdf:Property>
```

One RDF instance

```
<AgricZoning:Country rdf:about="&AgricZoning;pais_55"
     AgricZoning:nameBR="BRASIL" rdfs:label="BRASIL">
    <AgricZoning:officialRegionsOfCountry
    rdf:resource="&AgricZoning;regof_1"/>
    <AgricZoning:officialRegionsOfCountry
    rdf:resource="&AgricZoning;regof_2"/>
    <AgricZoning:officialRegionsOfCountry
    rdf:resource="&AgricZoning;regof_3"/>
    <AgricZoning:officialRegionsOfCountry
    rdf:resource="&AgricZoning;regof_4"/>
    <AgricZoning:officialRegionsOfCountry
    rdf:resource="&AgricZoning;regof_5"/>
    <AgricZoning:statesOfCountry rdf:resource="&AgricZoning;estado_11"/>
    <AgricZoning:statesOfCountry rdf:resource="&AgricZoning;estado_12"/>
:
    <AgricZoning:metroAreasOfCountry
    rdf:resource="&AgricZoning;metro_5201"/>
:
</AgricZoning:Country>
```

RDF-Schema to provide Alternative Knowledge Views



OWL – Ontology Web Language

- Extends the RDF with standard vocabulary and constructs to define:
  - Local scope of properties
  - Disjointness of classes
  - Boolean combinations of classes
  - Cardinality restrictions
  - Special characteristics of properties (e.g., transitive properties, inverted properties)

The 3 flavours of OWL

- **OWL Lite**
  - ♦ Restricted expressiveness: excludes enumerated classes, disjointness statements, and arbitrary cardinality
  - Easier to grasp and implement
- **OWL DL**
  - Equivalent to Description Logics
  - Still permits efficient reasoning support
  - Every legal OWL DL document is a legal RDF document (but not the inverse)
- **OWL Full**
  - Fully upward-compatible with RDF, both syntactically and semantically
  - Any valid RDF/RDF Schema conclusion is also a valid OWL Full conclusion
  - Undecidable

Disjunction and Equivalence of Classes

```
<owl:Class rdf:about="#associateProfessor">
    <owl:disjointWith rdf:resource="#professor"/>
    <owl:disjointWith rdf:resource="#assistantProfessor"/>
</owl:Class>

<owl:Class rdf:ID="faculty">
    <owl:equivalentClass
    rdf:resource="#academicStaffMember"/>
</owl:Class>
```

Inverse properties

```
<owl:ObjectProperty rdf:ID="teaches">
   <rdfs:range rdf:resource="#course"/>
   <rdfs:domain rdf:resource="#academicStaffMember"/>
   <owl:inverseOf rdf:resource="#isTaughtBy"/>
</owl:ObjectProperty>
```

Abstract OWL Syntax

```
Class(Person partial
    restriction (hasChild allValuesFrom(Person)))

Class(Parent complete
   Person
    restriction (hasChild someValuesFrom(Person)))

ObjectProperty(hasChild)

Individual (John type(Person)
   value(hasChild Mary))
```

Rule Languages

Rules:

- father(?x, ?z) v mother(?x, ?z) ⇒ parent(?x, ?z)
- parent(?x, ?z) ∧ parent(?y, ?z) ⇒ brother(?x, ?y)

Knowledge base:

- father(_Fileto, _Claudio)
- father(_Guiga, _Claudio)

:

Query:

- brother(_Fileto, ?b)

⇒ Yes !!!
⇒ ?b = _Guiga
⇒ ?b = _xyz1, _xyz2, _xyz3, _xyz4, ...

SPARQL

W3C recommendation for querying RDF repositories

Exemplo de expressão em SPARQL:

```
SELECT ?concept, ?property, “Mary”
    WHERE {
    ?concept property:hasProperty ?property
    FILTER(?property, "name")
}
```

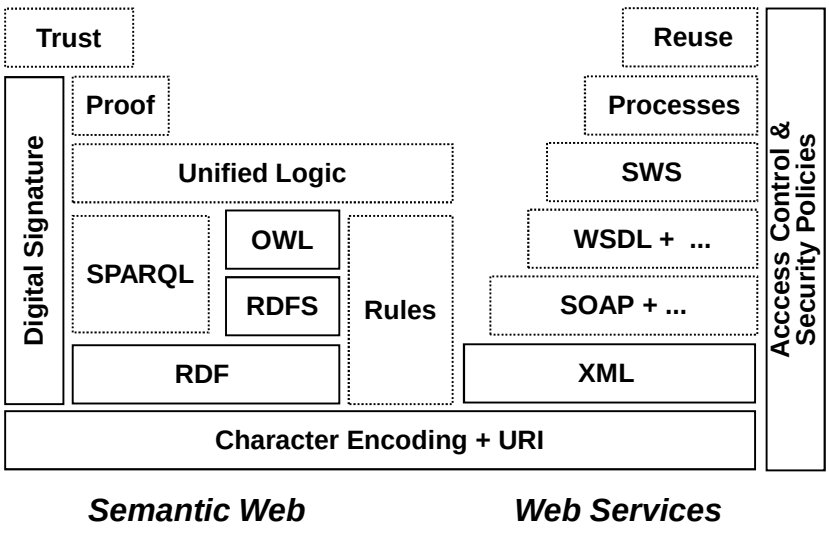
Research Challenges in the Semantic Web

- **Ontology Creation and Management**
  - (Semi)-Automated Ontology Building (+)
  - (Semi)-Automated Semantic Annotation (+)
  - (Semi)-Automated Ontology Evolution (+/-)
  - Reasoning with Inconsistent Ontologies (-)
  - Ontology Mapping, Mediation and Alignment (+)
- **Ontology Use**
  - Ontologies for Knowledge Management (+/-)
  - Semantic IR / Search (++)
  - Semantic Web Services (++ -> future)
- **Tools and Application (++)**

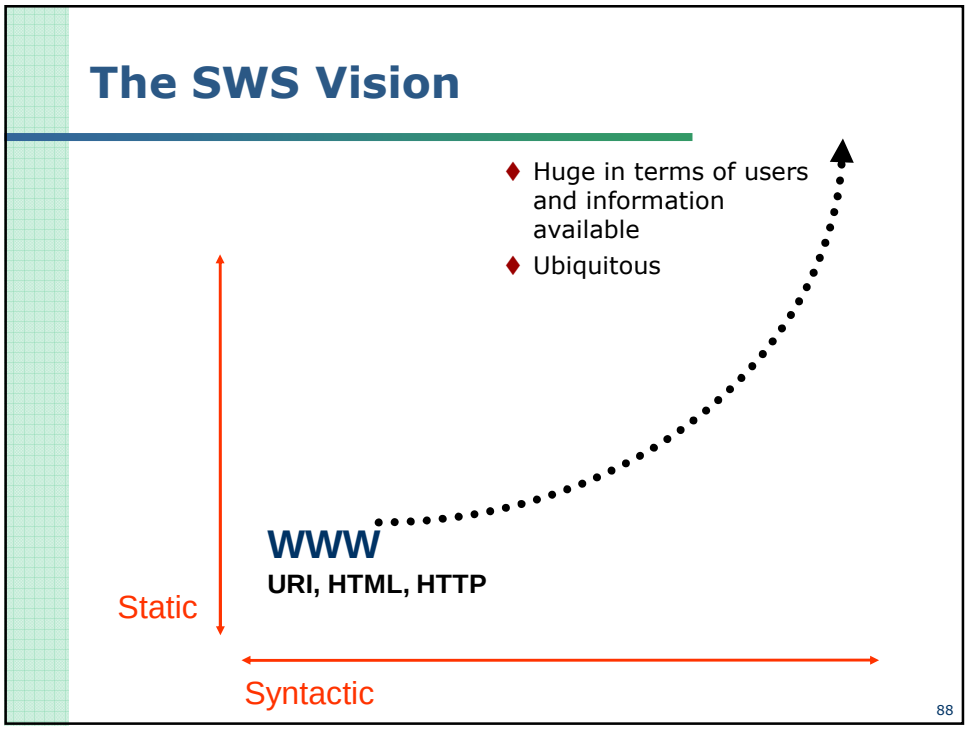
Topics

- **Introduction**
- **Web Services (WS)**
- **Semantic Web (SW)**
- **Semantic Web Services (SWS)**
- **Some Major Efforts towards SWS**
  - WSDL-S
  - OWL-S
  - SWSF (SWSO + SWSL)
  - WSMO (WSMO + WSML + WSMX)
- **Software Tools:** WSMT, WSMX, IRS-III, ...
- **Case study: Travelling to SBBD**

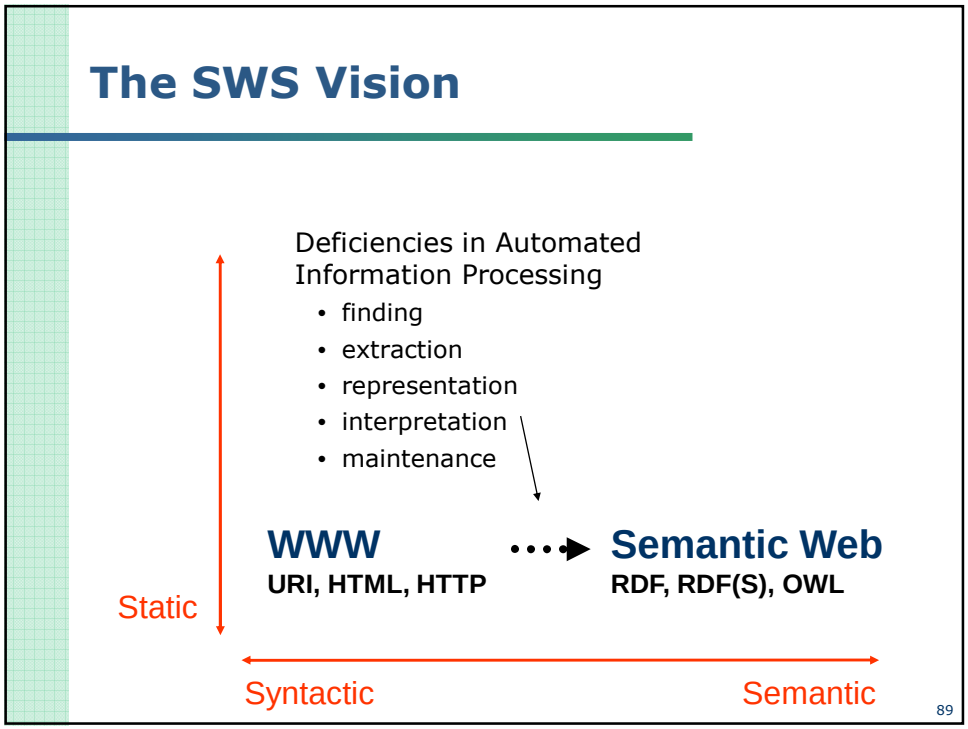
Semantic Web & Web Services



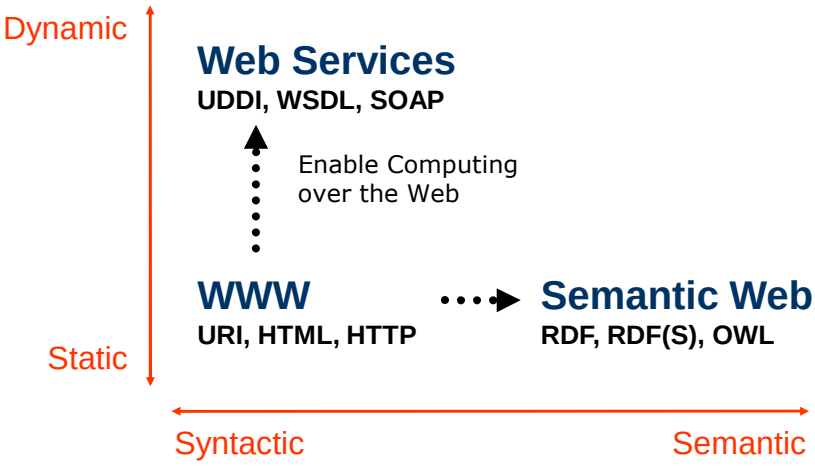
The SWS Vision



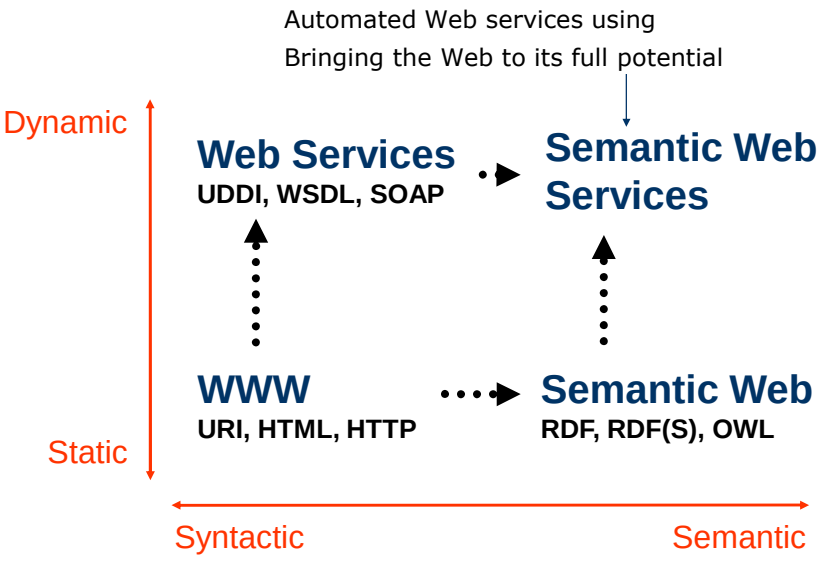
The SWS Vision



The SWS Vision



The SWS Vision



Semantic description of Web Services

- Should describe all information necessary to enable automated discovery, composition, execution, etc.
- Semantically enhanced repositories
- Tools and platforms that:
  - semantically enrich current Web content
  - facilitate discovery, composition and execution

Semantic Web Services

- define exhaustive description frameworks for describing Web Services and related aspects **(Web Service Description Ontologies)**
- support ontologies as underlying data model to allow machine supported Web data interpretation **(Semantic Web aspect)**
- define semantically driven technologies for automation of the Web Service usage process **(Web Service aspect)**

What (partial) automation should SWS provide?

- **Publication**: Make available the description of the capability of a service
- **Discovery**: Locate different services suitable for a given task
- **Selection**: Choose the most appropriate services among the available ones
- **Composition**: Combine services to achieve a goal
- **Mediation**: Solve mismatches (data, protocol, process) among the combined
- **Execution**: Invoke services following programmatic conventions
- **Monitoring**: Control the execution process
- **Compensation**: Provide transactional support and undo or mitigate unwanted effects
- **Replacement**: Facilitate the substitution of services by equivalent ones

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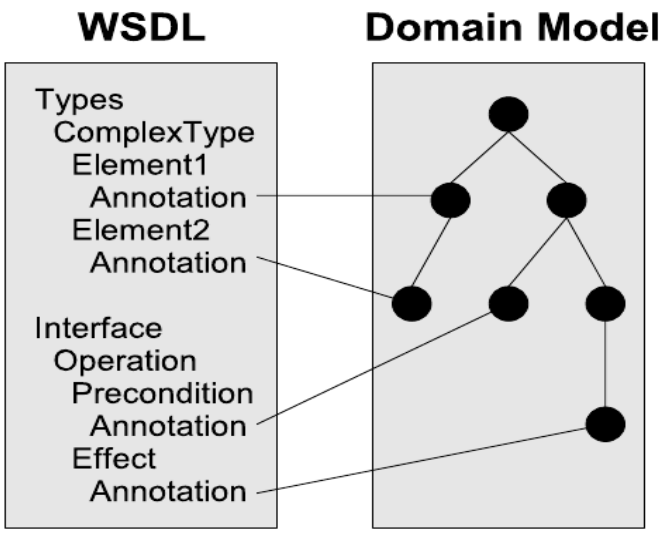
Some Major SWS Proposals

- **WSDL-S: extends WS** technology with semantic descriptions
- **OWL-S: extends OWL** for semantically describing WS
- **SWSF (SWSO + SWSL):** roots in **OWL-S** and the **PSL** (Process Specification Language)
- **WSMO (WSMO + WSML + WSMX):** ontologies, Web services, **goals**, and **mediators**

WSDL-S

- Rather **minimalist and lightweight** approach that **extends WSDL** service descriptions with semantics
- Roots on METEOR-S project, from **Amit Sheth** at LSDIS, Athens, Georgia
- The semantic model is outside WSDL-S, making it **impartial to ontology representation language**
- Builds upon and stays close to **existing industry standards**, promoting an upwardly compatible mechanism for adding semantics to Web services
- Support for XML Schema datatype annotations needs to be added to XML-Schema
- Originates of **SAWSDL** (Semantic Annotations for WSDL), W3C's recommendation with IBM

WSDL-S



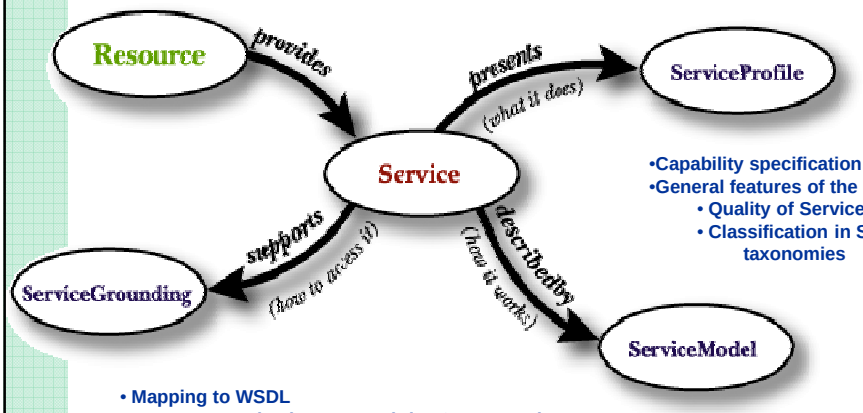
OWL-S

- OWL-S is an OWL ontology to describe Web services
- OWL-S leverages on OWL to
  - Support capability based discovery of Web services
  - Support automatic composition of Web Services
  - Support automatic invocation of Web services

"Complete do not compete"

- OWL-S does not aim to replace the Web services standards rather OWL-S attempts to provide a semantic layer
  - OWL-S relies on WSDL for Web service invocation *(see Grounding)*
  - OWL-s Expands UDDI for Web service discovery *(OWL-S/UDDI mapping)*

OWL-S Upper Ontology

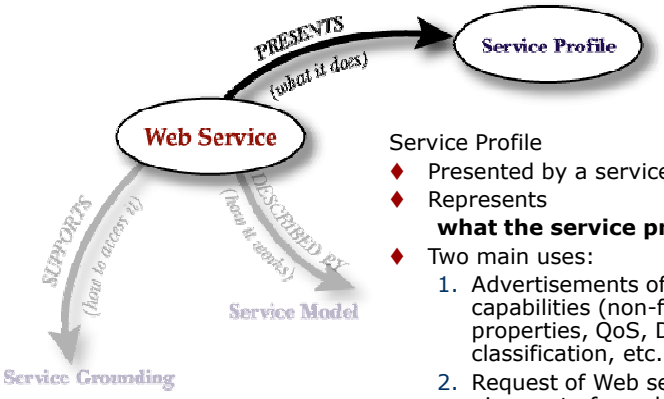


- Capability specification
- General features of the Service
  - Quality of Service
  - Classification in Service taxonomies

- Mapping to WSDL
  - communication protocol (RPC, HTTP, ...)
  - marshalling/serialization
  - transformation to and from XSD to OWL

- Control flow of the service
  - Black/Grey/Glass Box view
- Protocol Specification
- Abstract Messages

Service Profiles



Service Profile

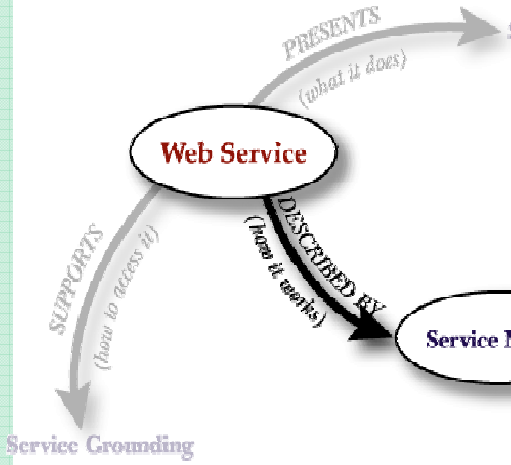
- Presented by a service.
- Represents
  what the service provides
- Two main uses:
  1. Advertisements of Web Services capabilities (non-functional properties, QoS, Description, classification, etc.)
  2. Request of Web services with a given set of capabilities

•Profile does not specify use/invocation!

OWL-S Service Profile
Capability Description

- **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)

Process Model



- Process Model
  - Describes how a service works: internal processes of the service
  - Specifies service interaction protocol
  - Specifies abstract messages: ontological type of information transmitted
- Facilitates
  - Web service invocation
  - Composition of Web services
  - Monitoring of interaction

Definition of Process

- A Process represents a transformation (function).
  It is characterized by four parameters
  - ***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
    - ***Condition***: under what condition the result occurs
    - ***Constraints on Outputs***
    - ***Effects***: real world changes resulting from the execution of the process

Example of an atomic Process

Inputs / Outputs

Precondition

Result

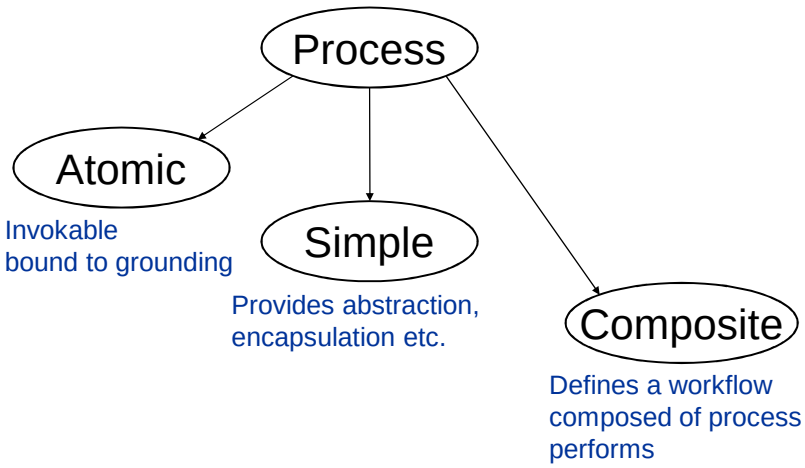
Condition

Output Constraints

Effect

```
<process:AtomicProcess rdf:ID="LogIn">
  <process:hasInput rdf:resource="#AcctName"/>
  <process:hasInput rdf:resource="#Password"/>
  <process:hasOutput rdf:resource="#Ack"/>
  <process:hasPrecondition isMember(AccName)/>
  <process:hasResult>
     <process:Result>
        <process:inCondition>
            <expr:SWRL-Condition>
             correctLoginInfo(AccName,Password)
          </expr:SWRL-Condition>
          </process:inCondition>
          <process:withOutput rdf:resource="#Ack">
            <valueType rdf:resource="#LoginAcceptMsg">
          </process:withOutput>
          <process:hasEffect>
              <expr:SWRL-Condition>
                loggedIn(AccName,Password)
              </expr:SWRL-Condition>
          </process:hasEffect>
     </process:Result>
  </process:hasResult>
</process:AtomicProcess>
```

Ontology of Processes



Process Model Organization

- **Process Model is described as a tree structure**
  - Composite processes are internal nodes
  - Simple and Atomic Processes are the leaves
- **Simple processes represent an abstraction**
  - Placeholders of processes that aren't specified
  - Or that may be expressed in many different ways
- **Atomic Processes correspond to the basic actions that the Web service performs**
  - Hide the details of how the process is implemented
  - Correspond to WSDL operations

~ related Process Definition Languages a la BPEL

Composite Processes

- Composite Processes specify how processes work together to compute a complex function
- Composite processes define

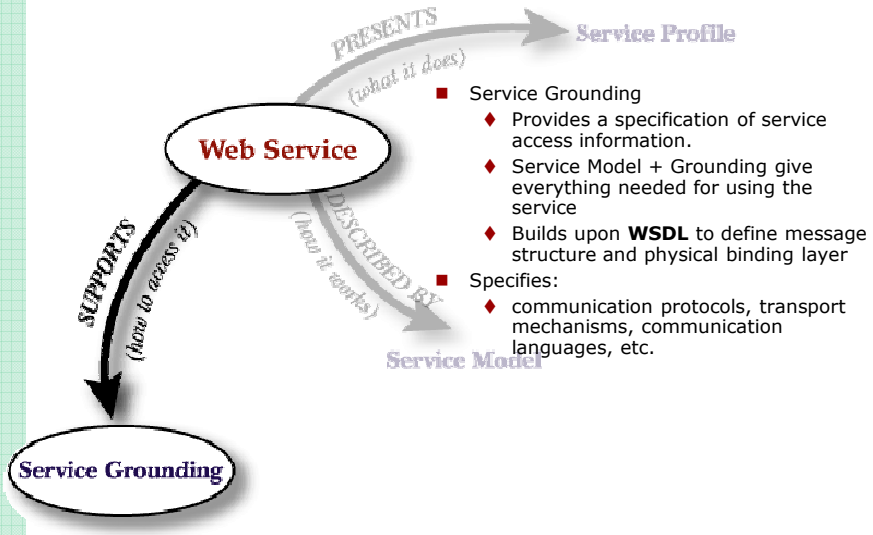
1. Control Flow

Specify the temporal relations between the executions of the different sub-processes (sequence, choice, etc.)

2. Data Flow

Specify how the data produced by one process is transferred to another process

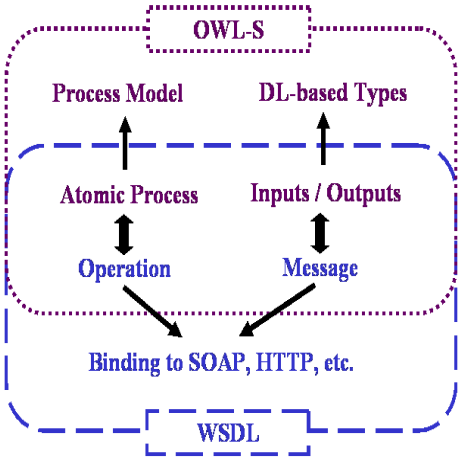
Service Grounding



- Service Grounding
  - Provides a specification of service access information.
  - Service Model + Grounding give everything needed for using the service
  - Builds upon **WSDL** to define message structure and physical binding layer
- Specifies:
  - communication protocols, transport mechanisms, communication languages, etc.

Mapping OWL-S / WSDL 1.1

- **Operations** correspond to Atomic Processes
- **Input/Output** messages correspond to Inputs/Outputs of processes



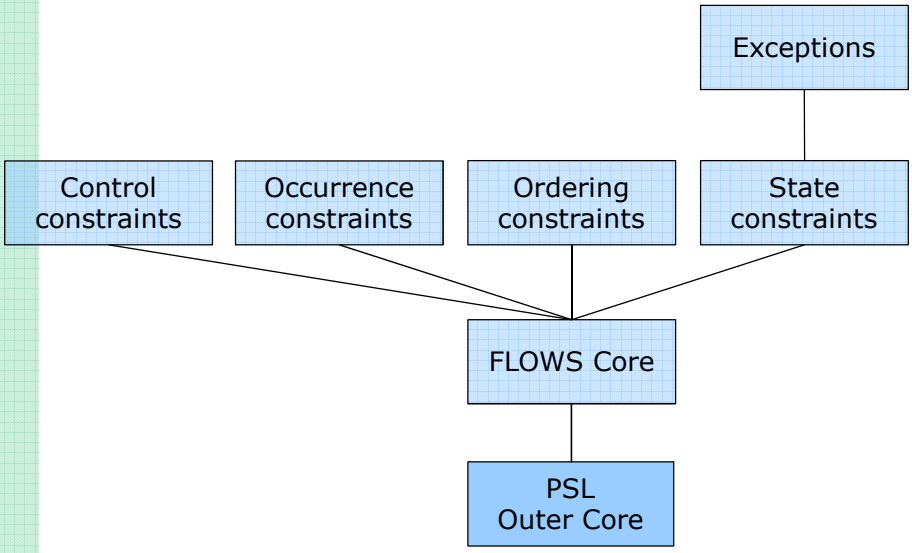
Result of using the Grounding

- Invocation mechanism for OWL-S
  - Invocation based on WSDL
  - Different types of invocation supported by WSDL can be used with OWL-S
- Clear separation between service description and invocation/implementation
  - Service description is needed to reason about the service
    - Decide how to use it
    - Decide what information to send and what to expect
  - Service implementation may be based on SOAP an XSD types
  - The crucial point is that the information that travels on the wires and the information used in the ontologies is the same
- Allows any web service to be represented using OWL-S

SWSF – Semantic Web Services Framework (SWSO + SWSL)

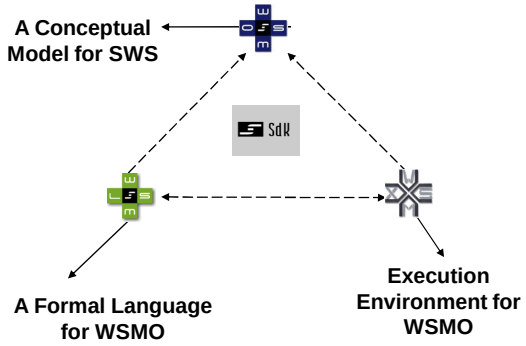
- Based on OWL-S and PSL (Process Specification Language)
- Richer behavioural process model based on PSL
- Two major components:
  - conceptual model to specify ontologies, called **SWSO**, and
  - a richer language, called **SWSL**
- Two variants of SWSL:
  - **SWSL-FOL**, based on FLOWS (First-order Logic Ontology for Web Services),
  - **SWSL-Rules**, based on ROWS (Rule Ontology for Web Services)
- Submitted to W3C in 2005
- Standardized by ISO 18269

FLOWS Extensions based on PSL

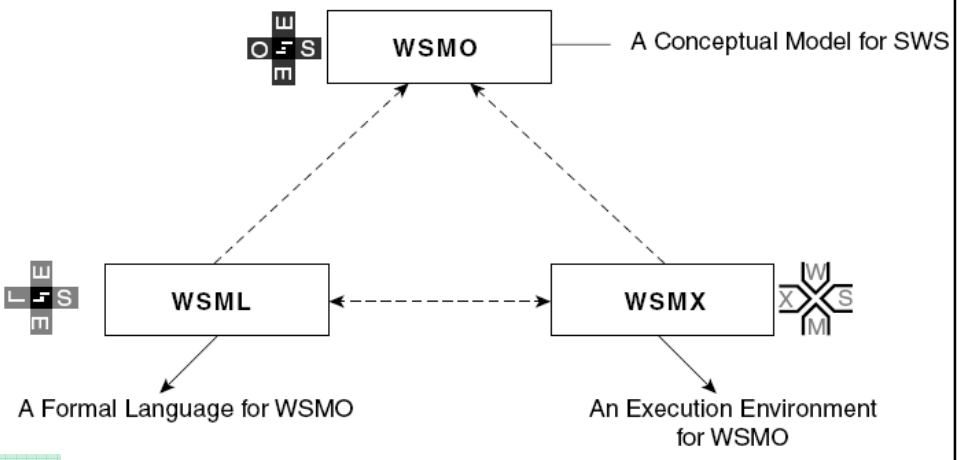


WSMO

- WSMO is an ontology and conceptual framework to describe Web services and related aspects
- Based Web Service Modeling Framework (WSMF)
- WSMO is a SDK-Cluster Working Group



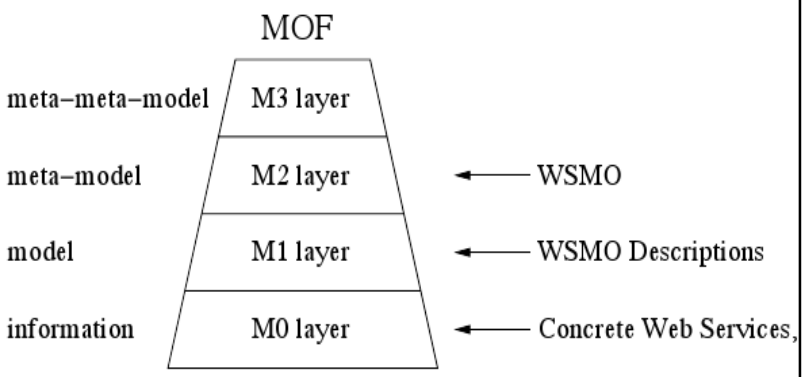
The WSMO approach for SWS



WSMO Principles

- **Web Compliance**
  - XML, URI (IRI), namespaces, **but not necessarily RDF/S, OWL, …**
- **Ontology-based & Role Separation**
  - **Users exist in different contexts**
- **Strict Decoupling & Strong Mediation**
  - Autonomous components with **mediators for interoperability**
- **Interface vs. Implementation**
  - distinguish interface (= description) from implementation (=program)
  - WSML
- **Execution Semantics**
  - WSMX
- **Services vs Web Services**
  - A **Web service** is a computational entity which is able to achieve a user's goal by invocation (e.g., sell books, sell air tickets)
  - A **service** is the actual value provided by this invocation

WSMO model in MOF



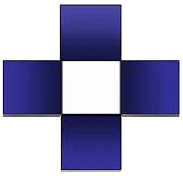
WSMO Top Level Concepts

Objectives that a client may have when consulting a Web Service

Goals

Provide the formally specified terminology of the information used by all other components

Ontologies



Web Services

Semantic description of Web Services

Mediators

Connectors between components with mediation facilities for handling heterogeneities

Non-Functional Properties

- Every WSMO elements is described by properties that contain relevant, non-functional aspects of the item
- used for management and element overall description
- **Core Properties:**
  - **Dublin Core Metadata Element Set** plus **version** (evolution support)
  - W3C-recommendations for description type
- **Web Service Specific Properties:**
  - quality aspects and other non-functional information of Web Services
  - used for Service Selection

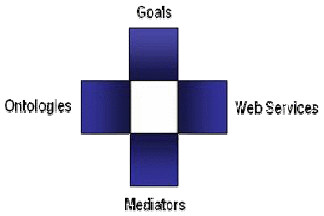
Non-Functional Properties

```
ontology _"http://www.example.org/ontologies/example"
 nfp
   dc#title hasValue "WSML example ontology"
   dc#subject hasValue "family"
   dc#description hasValue "fragments of a family ontology to provide WSML examples"
   dc#contributor hasValue { _"http://homepage.uibk.ac.at/~c703240/foaf.rdf",
    _"http://homepage.uibk.ac.at/~csaa5569/",
    _"http://homepage.uibk.ac.at/~c703239/foaf.rdf",
    _"http://homepage.uibk.ac.at/homepage/~c703319/foaf.rdf" }
   dc#date hasValue _date("2004-11-22")
   dc#format hasValue "text/plain"
   dc#language hasValue "en-US"
   dc#rights hasValue _"http://www.deri.org/privacy.html"
   wsml#version hasValue "$Revision: 1.13 $"
 endnfp
```

WSMO Ontologies

Objectives that a client may have when consulting a Web Service

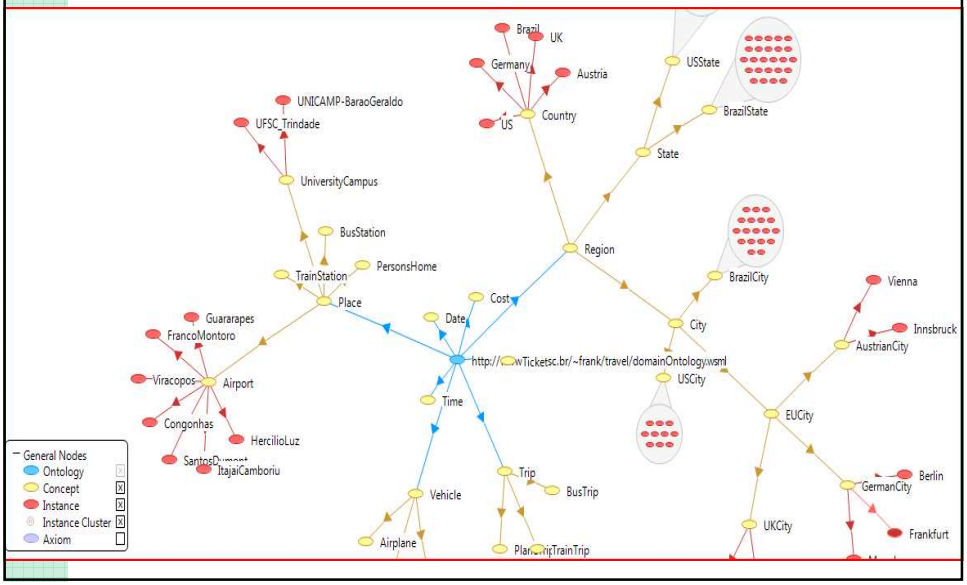
Provide the formally specified terminology of the information used by all other components



Semantic description of Web Services

Connectors between components with mediation facilities for handling heterogeneities

Ontology Example



Ontology class

Class ontology
- hasNonFunctionalProperty type nonFunctionalProperty
- importsOntology type ontology
- usesMediator type ooMediator
- hasConcept type concept
- hasRelation type relation
- hasFunction type function
- hasInstance type instance
- hasAxiom type axiom

Ontology header

```
wsmlVariant _"http://www.wsmo.org/wsml/wsml-syntax/wsml-flight"
namespace {
   _"http://www.inf.ufsc.br/~frank/travel/domainOntology#",
    dc _"http://purl.org/dc/elements/1.1#",
    wsml _"http://www.wsmo.org/wsml/wsml-syntax#" }

ontology _"http://www.inf.ufsc.br/~frank/travel/domainOntology.wsml"
    nonFunctionalProperties
        dc#date hasValue _date(2008,10,8)
        dc#format hasValue "text/plain"
        dc#contributor hasValue {"Frank Siqueira", "Adina Sirbu",
   "Renato Fileto"}
        dc#title hasValue {"SBBD Travel Ontology", "Travel Ontology"}
        dc#language hasValue "en-US"
    endNonFunctionalProperties
```

Concepts and relations

```
concept Country subConceptOf Region
    name ofType _string
    capital impliesType  (0 1) City

concept City subConceptOf Region
    name ofType _string
    country ofType Country

concept BrazilCity subConceptOf City

concept Ticket
    from ofType Region
    to ofType Region
    vehicle ofType Vehicle
```

Concepts and relations (cont.)

```
concept Place
    isInCity impliesType  (0 1) City

concept Airport subConceptOf Place

concept BusStation subConceptOf Place

concept TrainStation subConceptOf Place

concept PersonsHome subConceptOf Place

concept UniversityCampus subConceptOf Place
```

Instances

```
instance Brazil memberOf Country
    name hasValue "Brazil"
    capital hasValue Brasilia

instance SP memberOf BrazilState
    name hasValue "São Paulo"
    country hasValue Brazil

instance Brasilia memberOf BrazilCity
    name hasValue "Brasília"
    country hasValue Brazil
```

Instances (cont.)

instance UNICAMP-BaraoGeraldo memberOf UniversityCampus
    isInCity hasValue Campinas

instance UFSC_Trindade memberOf UniversityCampus
    isInCity hasValue Florianopolis

instance HercilioLuz memberOf Airport
    isInCity hasValue Florianopolis

instance Viracopos memberOf Airport
    isInCity hasValue Campinas
instance Congonhas memberOf Airport
    isInCity hasValue SaoPaulo
instance FrancoMontoro memberOf Airport
    isInCity hasValue Guarulhos

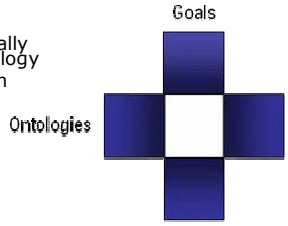
Axioms

axiom **UKCityDef**
    definedBy
        ?city memberOf UKCity
        implies
            ?city[country hasValue UK]

axiom **BrazilCityDef**
    definedBy
        ?city memberOf BrazilCity
        implies
            ?city[country hasValue Brazil]

WSMO Goals

Objectives that a client may have when consulting a Web Service



Provide the formally specified terminology of the information used by all other components

Semantic description of Web Services:
- **Capability** *(functional)*
- **Interfaces** *(usage)*

Connectors between components with mediation facilities for handling heterogeneities

Goal class

Class goal
hasNonFunctionalProperty type nonFunctionalProperty
importsOntology type ontology
usesMediator type {ooMediator, ggMediator}
requestsCapability type capability multiplicity = single−valued
requestsInterface type interface

Goals

- **De-coupling of Request and Service**

  Goal-driven Approach, derived from AI rational agent approach

  - Requester formulates objective independent / without regard to services for resolution
  - 'Intelligent' mechanisms detect suitable services for solving the Goal
  - Allows re-use of Goals

- **Usage of Goals within Semantic Web Services**

  - A Requester, that is an agent (human or machine), defines a Goal to be resolved
  - Web Service Discovery detects suitable Web Services for solving the Goal automatically
  - Goal Resolution Management is realized in implementations

Goal Example

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

namespace
    {_"http://www.inf.ufsc.br/~frank/travel/goalFloripaCampinasSBBD2008#",
    dO _"http://www.inf.ufsc.br/~frank/travel/domainOntology#",
      dc _"http://purl.org/dc/elements/1.1#"}

/* Test Goal */
goal
    _"http://www.inf.ufsc.br/~frank/travel/goalFloripaCampinasSBBD2008.wsml"
nfp
dc#title hasValue "Goal"
dc#contributor hasValue "Frank Siqueira, Renato Fileto"
dc#description hasValue "Buying a ticket from Floripa to Campinas"
endnfp
importsOntology _"http://www.inf.ufsc.br/~frank/travel/domainOntology.wsml"
```

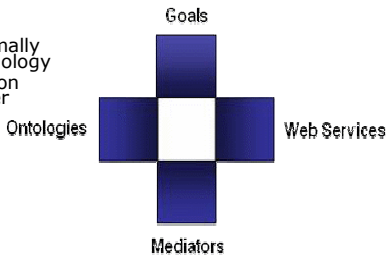
Goal Example (cont)

capability goalCapability
postcondition
definedBy
?ticket[
dO#from hasValue ?from,
dO#to hasValue ?to,
dO#vehicle hasValue ?vehicle
] memberOf dO#Ticket and
?from = dO#Florianopolis and
?to = dO#Campinas.

WSMO Web Services

Objectives that a client may have when consulting a Web Service

Provide the formally specified terminology of the information used by all other components



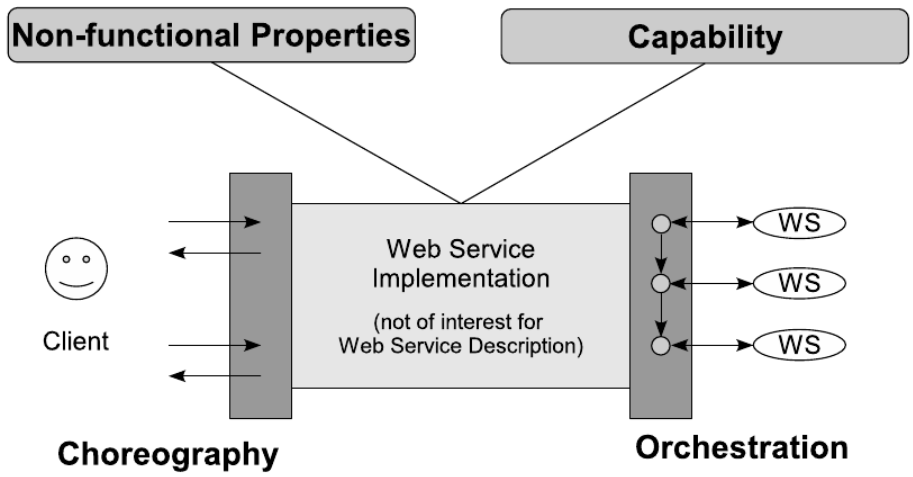
Semantic description of Web Services:
- **Capability** *(functional)*
- **Interfaces** *(usage)*

Connectors between components with mediation facilities for handling heterogeneities

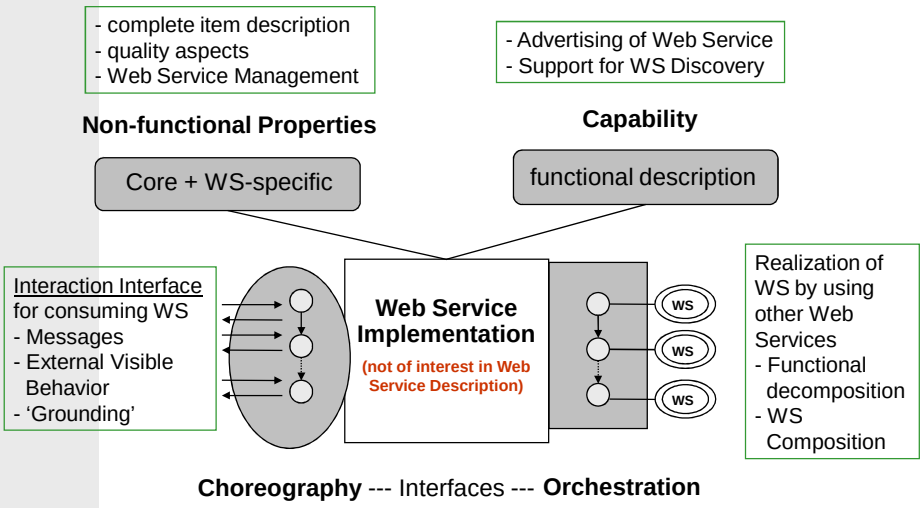
WSMO Service

Class service
hasNonFunctionalProperty type nonFunctionalProperty
importsOntology type ontology
usesMediator type {ooMediator, wwMediator}
hasCapability type capability multiplicity = single−valued
hasInterface type interface

WSMO Web Service



WSMO Web Service - Interfaces



Web Service specific Properties

- non-functional information of Web Services:

Accuracy
Availability
Financial
Network-related QoS
Performance
Reliability
Robustness
Scalability
Security
Transactional
Trust

Web Service Example

```
wsmlVariant _"http://www.wsmo.org/wsml/wsml-syntax/wsml-flight"
namespace { _"http://www.inf.ufsc.br/~frank/travel/webServiceBrazilAir#",
    dO _"http://www.inf.ufsc.br/~frank/travel/domainOntology#",
     dc _"http://purl.org/dc/elements/1.1#"}

webService _"http://www.inf.ufsc.br/~frank/travel/webServiceBrazilAir.wsml"
   nonFunctionalProperties
        dc#description hasValue "Booking plane tickets within Brazil"
        dc#contributor hasValue "Frank Siqueira"
        dc#title hasValue "Brazil Air"
    endNonFunctionalProperties

    importsOntology
         _"http://www.inf.ufsc.br/~frank/travel/domainOntology.wsml"
```

Web Service Example (cont.)

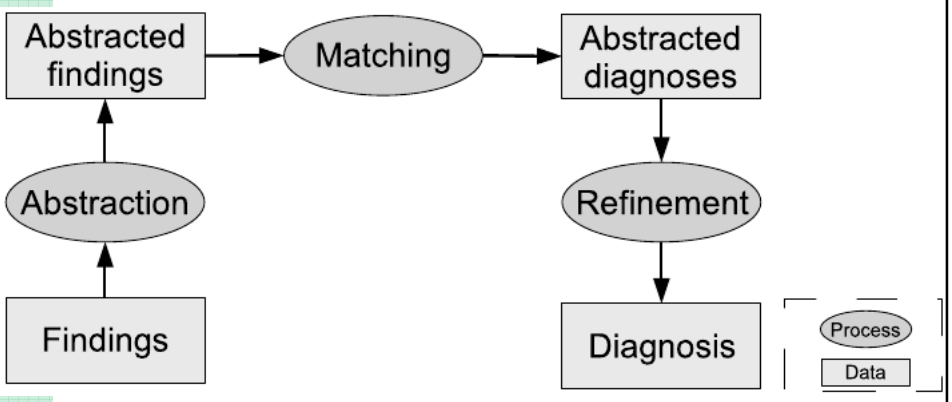
```
capability webServiceBrazilAirCapability

postcondition
    definedBy
        ?ticket[
            dO#from hasValue ?from,
            dO#to hasValue ?to,
            dO#vehicle hasValue ?vehicle
        ] memberOf dO#Ticket and
        ?from memberOf dO#BrazilCity and
        ?to memberOf dO#BrazilCity and
        ?vehicle memberOf dO#Airplane
```

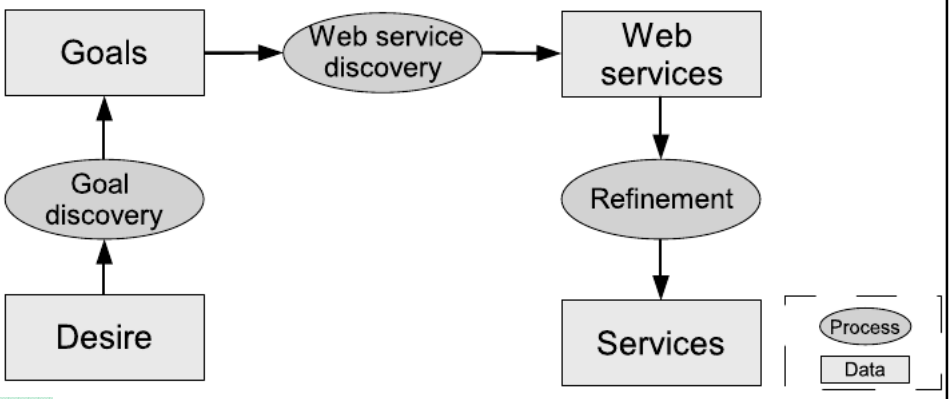
Goal-Services Matchmaking

- **Service:** provision of value for some domain
- **Abstract service:** collection of services offered by a provider
- **Goal:** specification of the client needs
  - *E.g.: Booking air tickets from Floripa to Campinas and booking a room in a hotel in Campinas without carpet*
- **Concrete services:** what the provide requires for accessing its services
  - *E.g. Persons' name, features of the flight, features of the hotel room (maybe a picture)*
- **Web service:** entity using standard interfaces that allow clients to interact with a provider, in order to explore and consume concrete services

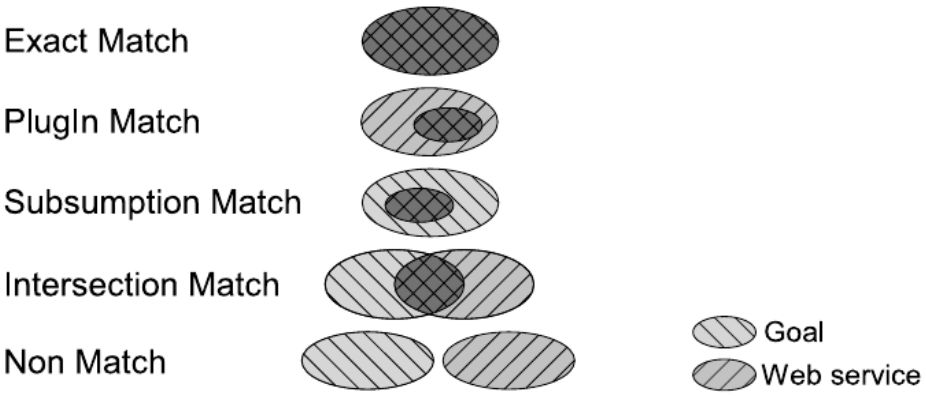
Heuristic Classification



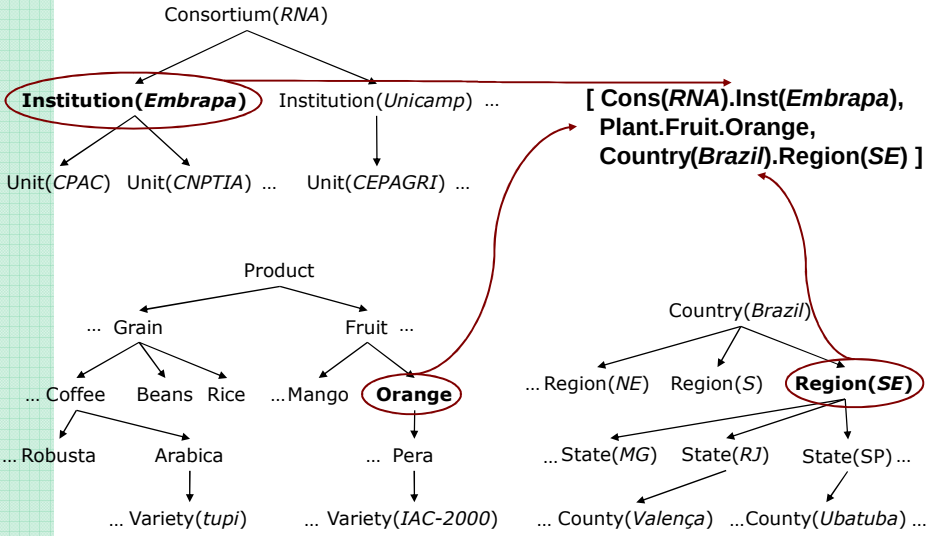
Services Discovery Process



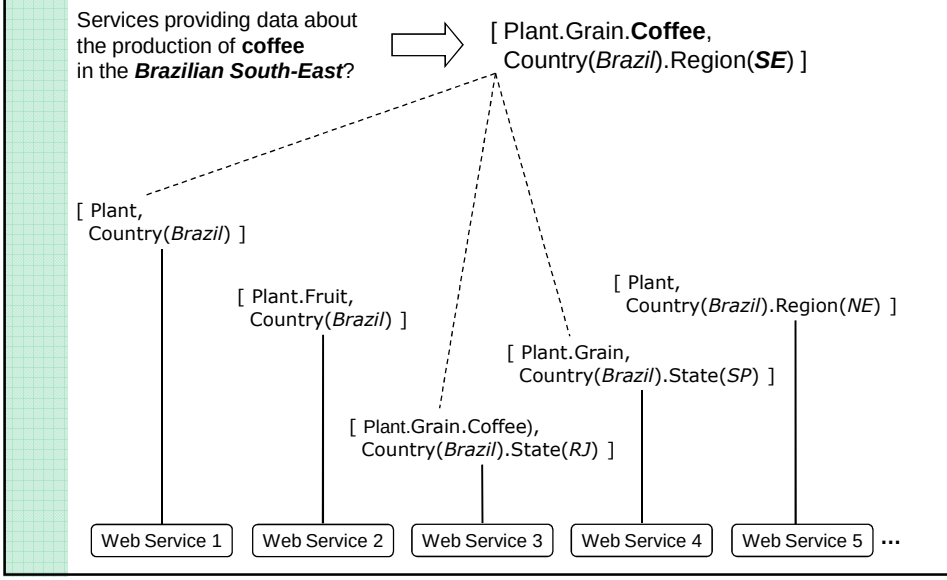
Possible kinds of matching



Ontological Coverage
(Fileto et al. 2003)



Relating Ontological Coverages for Web Services Discovering

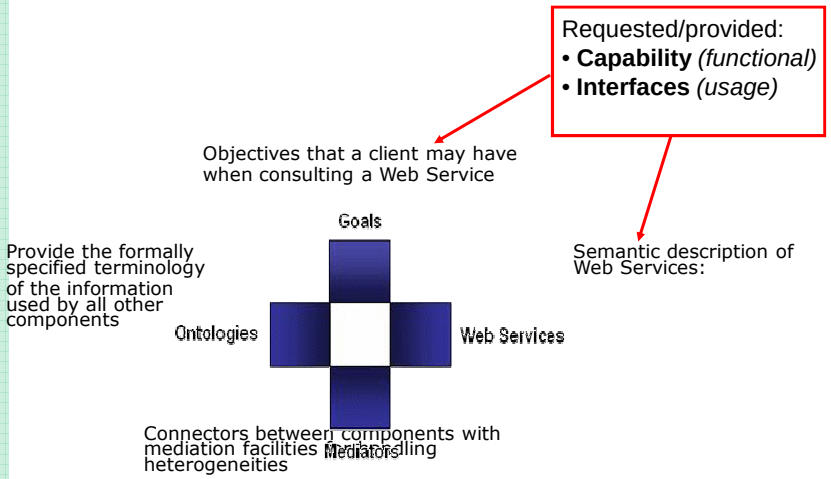


Formal Relationships between Ontological Coverages

Let OC = [t_1, t_2, t_n], OC′ = [t'_1, t'_2, t'_n] be ontological coverages, where t_i , t'_j are terms from the same ontology

- **Overlapping** (reflexive, symmetric, transitive)
  - For all *t in OC* there exists *t′ in OC′* such that *t encompass t′ OR t′ encompass t*
  - For all *t′ in OC′* there exists *t in OC* such that *t encompass t′ OR t′ encompass t*
- **Encompassing** (reflexive, transitive)
  - For all *t in OC* there exists *t′ in OC′* such that *t encompass t′*
  - For all *t′ in OC′* there exists *t in OC* such that *t encompass t′*
- **Equivalence** (reflexive, symmetric, transitive)
  - For all *t in OC* there exists *t′ in OC′* such that *t encompass t′*
  - For all *t′ in OC′* there exists *t in OC* such that *t′ encompass t*

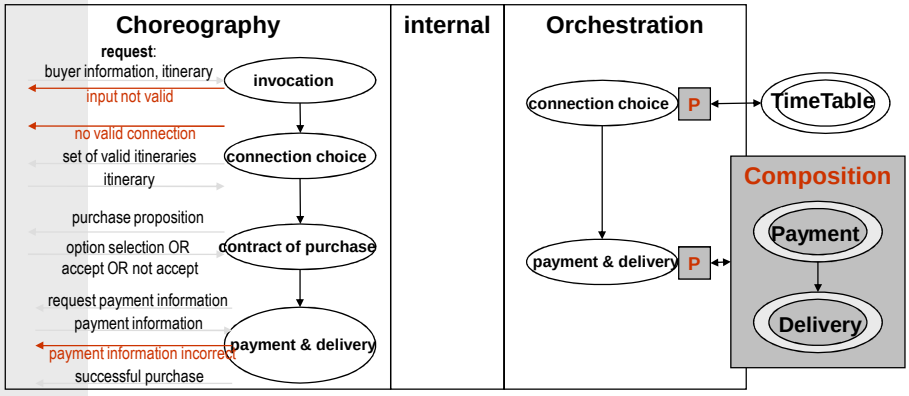
WSMO Capabilities/Interfaces



Capability Specification

- **Non functional properties**
- **Imported Ontologies**
- **Used mediators**
  - *OO Mediator:* importing ontologies as terminology definition
  - *WG Mediator:* link to a Goal that is solved by the Web Service
- **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**
  describes 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)

Web Service Interfaces



Choreography in WSMO

"Interface of Web Service for client-service interaction when consuming the Web Service"

- **External Visible Behavior**
  - those aspects of the workflow of a Web Service where User Interaction is required
  - described by process / workflow constructs
- **Communication Structure**
  - messages sent and received
  - their order (messages are related to activities)

Choreography in WSMO (2)

- **Grounding**
  - concrete communication technology for interaction
  - choreography related errors (e.g. input wrong, message timeout, etc.)
- **Formal Model**
  - allow operations / mediation on Choreographies
  - Formal Basis: Abstract State Machines (ASM)
- Very generic description of a transition system over evolving ontologies:

WSMO Orchestration

"Achieve Web Service Functionality by aggregation of other Web Services"

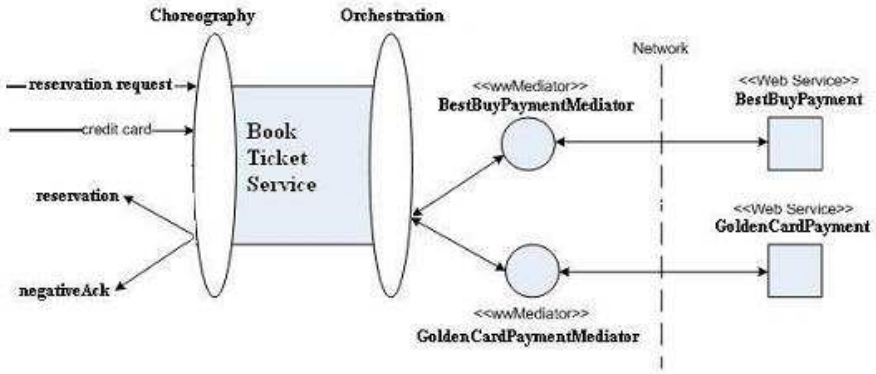
Decomposition of the Web Service functionality into sub functionalities

Proxies: Goals as placeholders for used Web Services

- **Orchestration Language**
  - decomposition of Web Service functionality
  - control structure for aggregation of Web Services
- **Web Service Composition**
  - Combine Web Services into higher-level functionality
  - Resolve mismatches occurring between composed Web Services
- **Proxy Technology**
  - Placeholders for used Web Services or goals, linked via Mediators.
  - Facility for applying the Choreography of used Web Services, service templates for composed services

Choreography & orchestration

- Example:



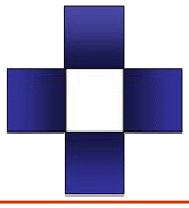
WSMO Mediators

Objectives that a client may have when consulting a Web Service

Goals

Provide the formally specified terminology of the information used by all other components

Ontologies



Web Services

Semantic description of Web Services:
- Capability *(functional)*
- Interfaces *(usage)*

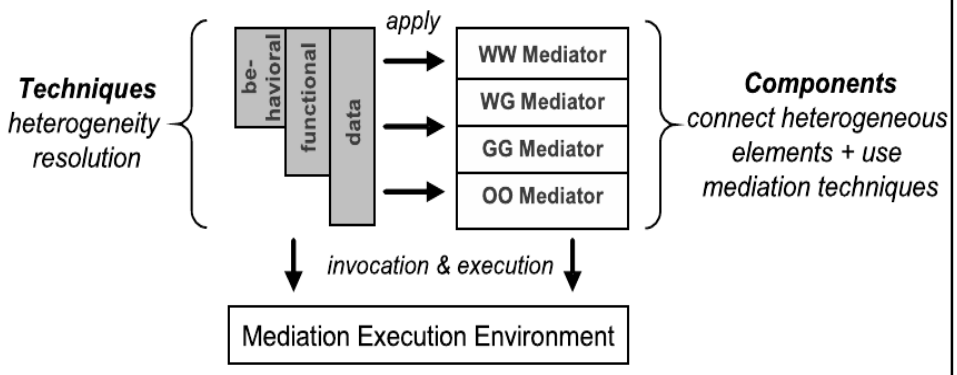
Mediators

Connectors between components with mediation facilities for handling heterogeneities

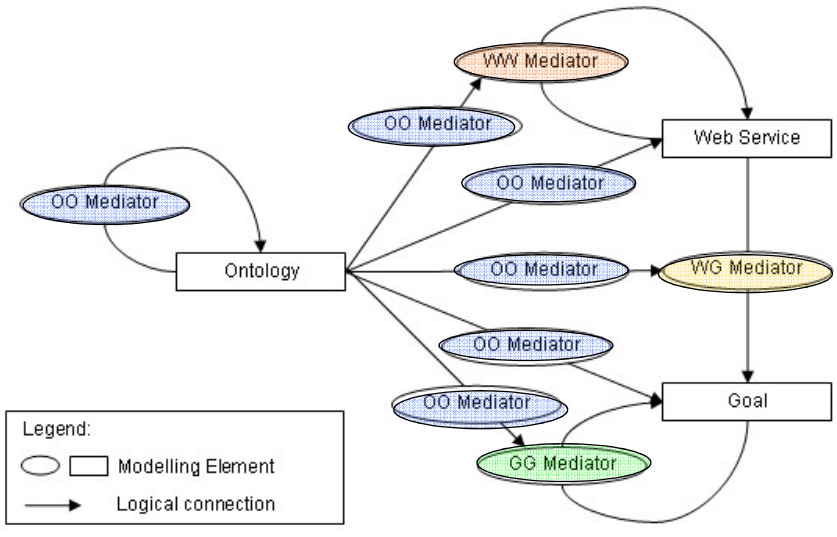
Mediation

- **Heterogeneity …**
  - Mismatches on structural / semantic / conceptual / level
  - Occur between different components that shall interoperate
  - Especially in distributed & open environments like the Internet
- **Concept of Mediation** (Wiederhold, 94):
  - ***Mediators*** as components that resolve mismatches
  - Declarative Approach:
    - Semantic description of resources
    - 'Intelligent' mechanisms that resolve mismatches independent of content
  - Mediation cannot be fully automated (integration decision)
- **Levels of Mediation within Semantic Web Services** (WSMF):
  - **Data Level:** mediate heterogeneous Data Sources
  - **Protocol Level:** mediate heterogeneous Communication Patterns
  - **Process Level:** mediate heterogeneous Business Processes

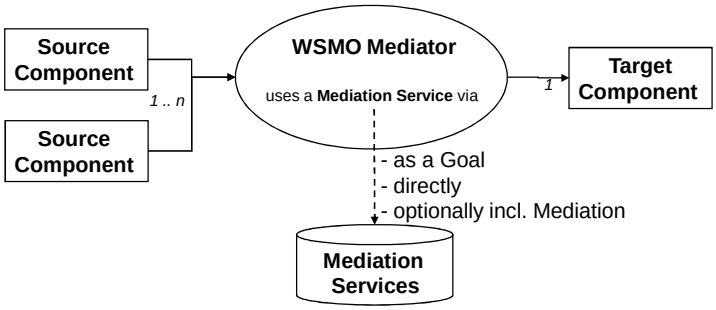
Mediation



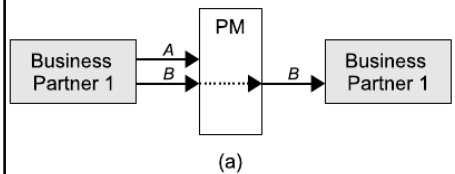
Mediator Usage



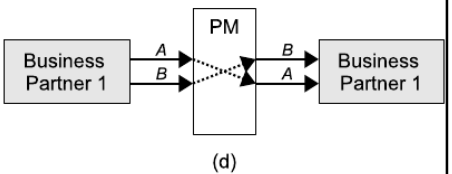
Mediators as services



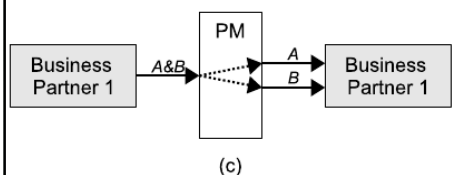
Process Mediation Patterns



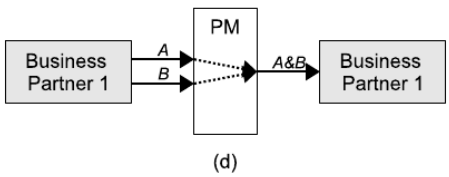
(a)



(d)

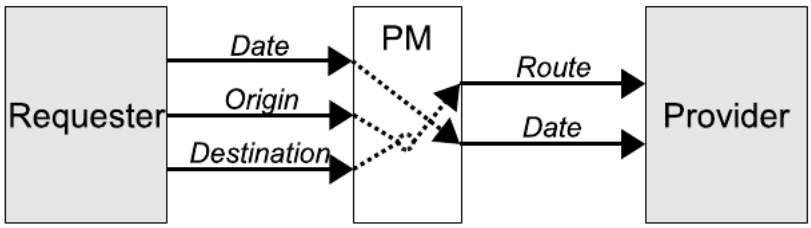


(c)



(d)

Example of Process Mediation



WSMO Perspective

- WSMO provides a **conceptual model** for Web Services and related aspects
  - WSMO separates the different **language specifications layers** (MOF style)
    - Language for defining WSMO is the meta – meta - model in MOF
    - WSMO and WSML are the meta - models in MOF
    - Actual goals, web services, etc. are the model layer in MOF
    - Actual data described by ontologies and exchanged is the information layer in MOF
  - Stress on solving the integration problem
    - Mediation as a key element
  - Languages to cover wide range of scenarios and improve interoperability
  - Relation to industry WS standards
  - All the way from conceptual modelling to usable implementation (WSML, WSMX)
  - Language: WSML: human radable syntax, XML exchange syntax, RDF/XML exchange syntax under consideration

WSML

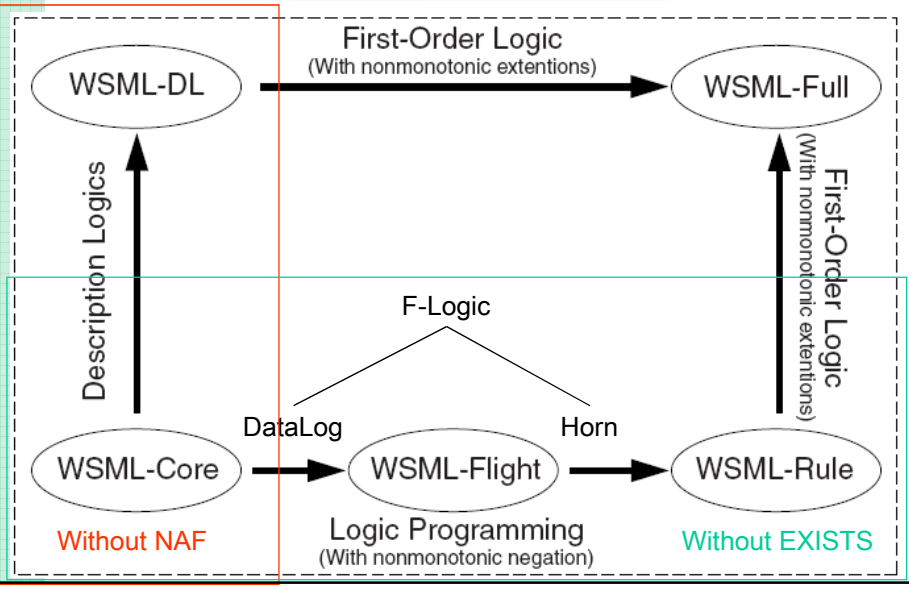
Key features:

- One syntactic framework for a set of layered languages
- Normative, human-readable syntax
- Separation of conceptual and logical modeling
- Semantics based on well-known formalisms
- WWW language
- Frame-based syntax

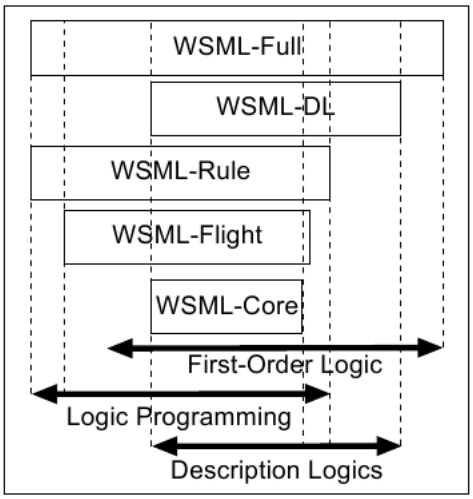
WSML vs OWL

- The relation between WSML and OWL+SWRL is still to be completely worked out:
  - WSML-Core is a subset of OWL Lite (DL Å Datalog)
  - WSML-DL is equivalent to OWL DL
  - WSML-Flight (refers to "F-Logic" and "Light" ;-) and extends to the LP variant of F-Logic) but for other languages the relation is still unknown.

WSML Variants



WSML Layering



Relation to Web Services Technology

	OWL-S	WSMO	*Web Services Infrastructure*
Discovery ***What it does***	Profile	Web Services (capability)	*UDDI API*
Choreography ***How is done***	Process Model	Orchestration + choreography	*BPEL4WS*
Invocation ***How to invoke***	Grounding+ WSDL/SOAP	Grounding	*WSDL/SOAP*

- OWL-S and WSMO map to UDDI API adding semantic annotation
- OWL-S and WSMO share a default WSDL/SOAP Grounding
- BPEL4WS could be mapped into WSMO orchestration and choreography
- Mapping still unclear at the level of choreography/orchestration
  - In OWL-S, multi-party interaction is obtained through automatic composition and invocation of multiple parties
  - BPEL allows hardcoded representation of many Web services in the same specification.
  - Trade-off: OWL-S support substitution of Web services at run time, such substitution is virtually impossible in BPEL.

Conclusion: **How WSMO Addresses WS problems**

- **Discovery**
  - Provide formal representation of capabilities and goal
  - Conceptual model for service discovery
  - Different approaches to web service discovery
- **Composition**
  - Provide formal representation of capabilities and choreographies
- **Invocation**
  - Support any type of WS invocation mechanism
  - Clear separation between WS description and implementation
- **Mediation and Interoperation**
  - Mediators as a key conceptual element
  - Mediation mechanism not dictated
  - (Multiple) formal choreographies + mediation enable interoperation
- **Guaranteeing Security and Policies**
  - No explicit policy and security specification yet
  - Proposed solution will interoperate with WS standards
- The solutions are envisioned maintaining a strong relation with existing WS standards

Topics

- **Introduction**
- **Web Services (WS)**
- **Semantic Web (SW)**
- **Semantic Web Services (SWS)**
- **Some Major Efforts towards SWS**
  - WSDL-S
  - OWL-S
  - SWSF (SWSO + SWSL)
  - WSMO (WSMO + WSML + WSMX)
- **Software Tools:** WSMT, WSMX, IRS-III, ...
- **Case study: Travelling to SBBD**

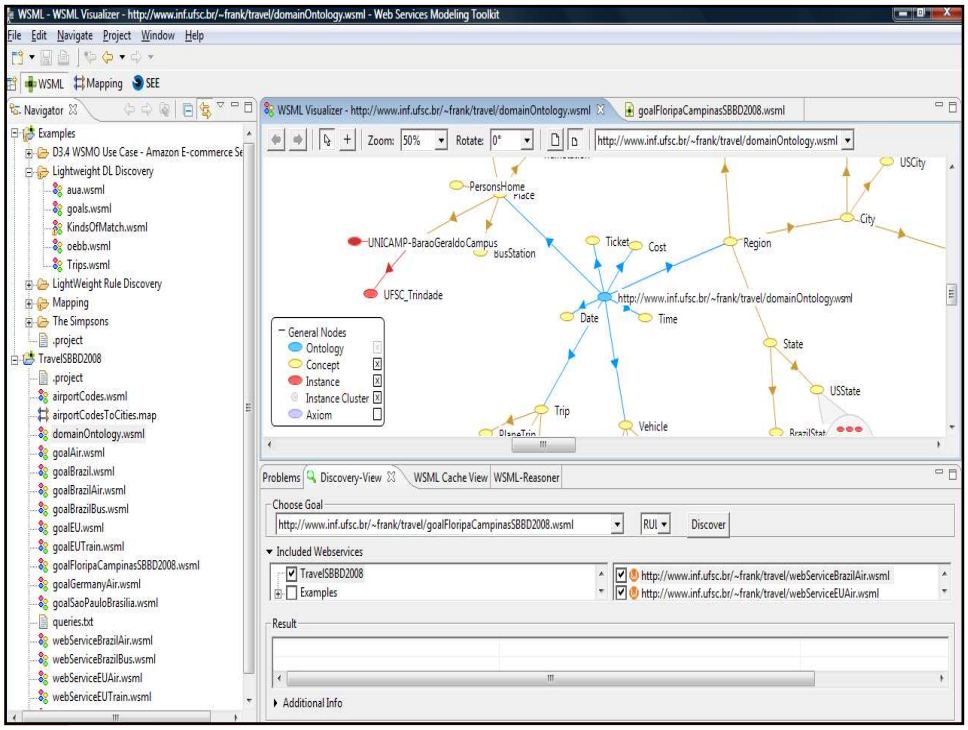
Software Tools for SWS

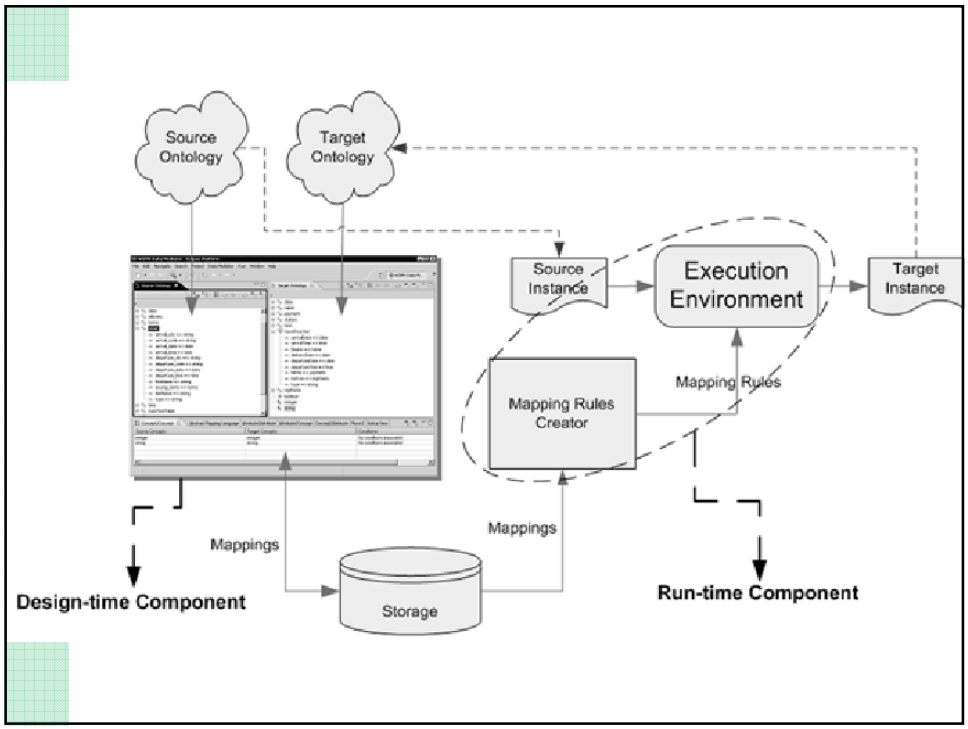
- Design Tools
  - WSMT (Eclipse, WSMO API, WSMO-Studio, WSMT, DOME)
- Execution Environments
  - WSMX
- Reasoners
  - WSML-2 Reasoner
  - IRS-III

WSMT

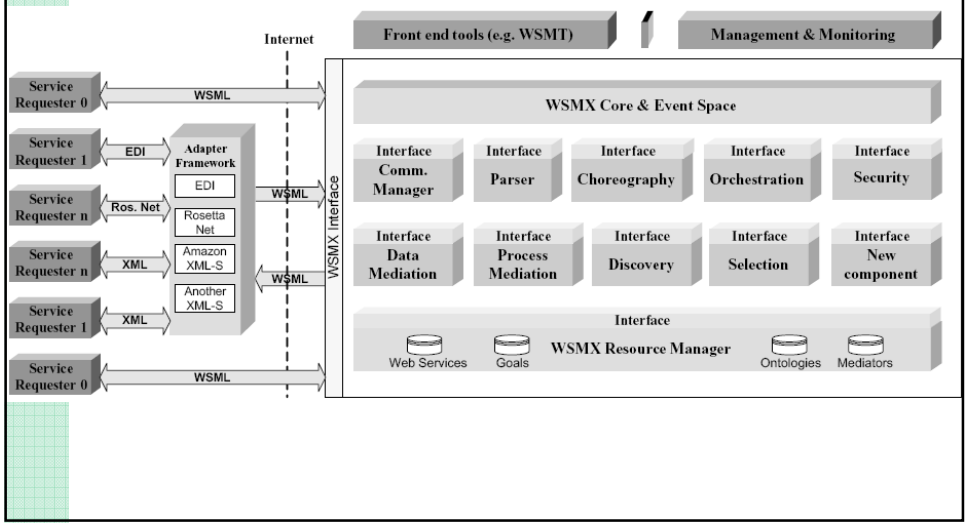
WSMT	WSMOStudio	DOME
graph based editing, integration of execution environments	*form based editing, support for choreographies*	tree based editing, support for versioning & distribution

Eclipse Platform	WSMO API

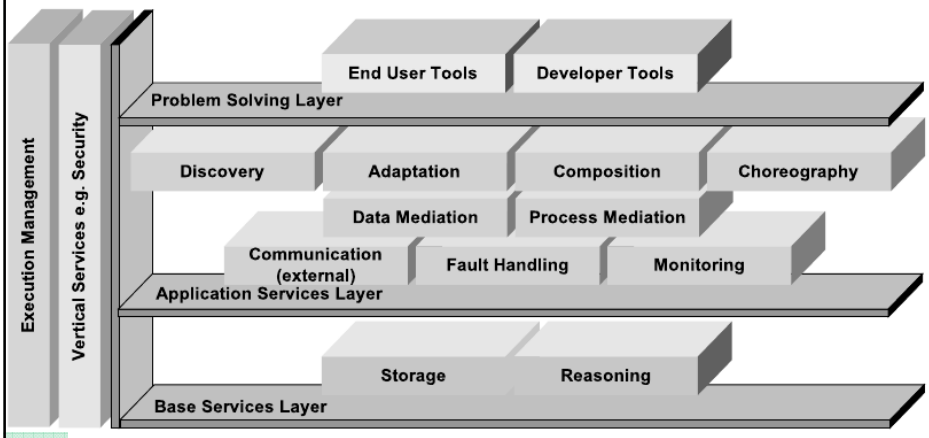




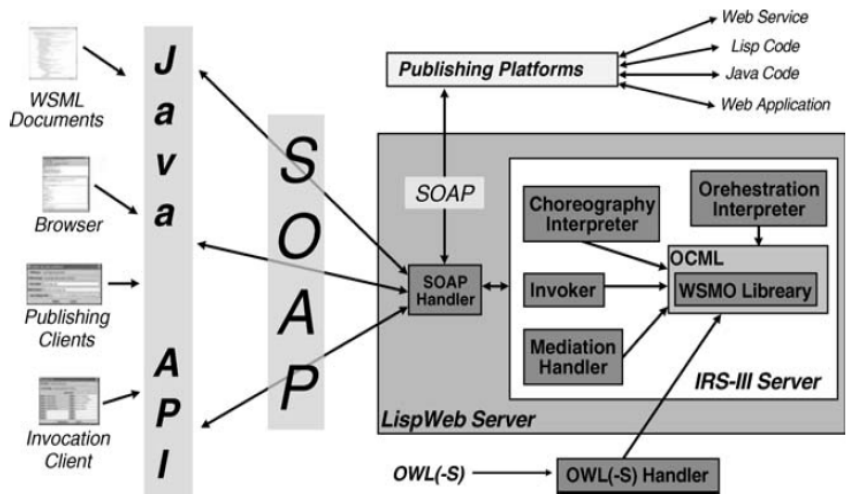
WSMX Architecture



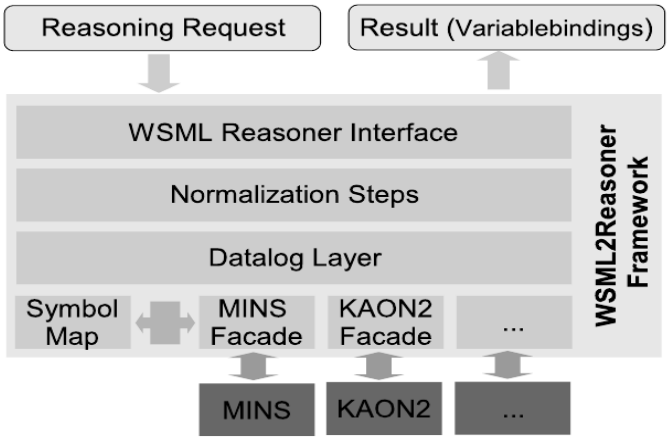
WSMX Execution Environment



IRS-III Server Architecture



WSML2REasoner Framework



Topics

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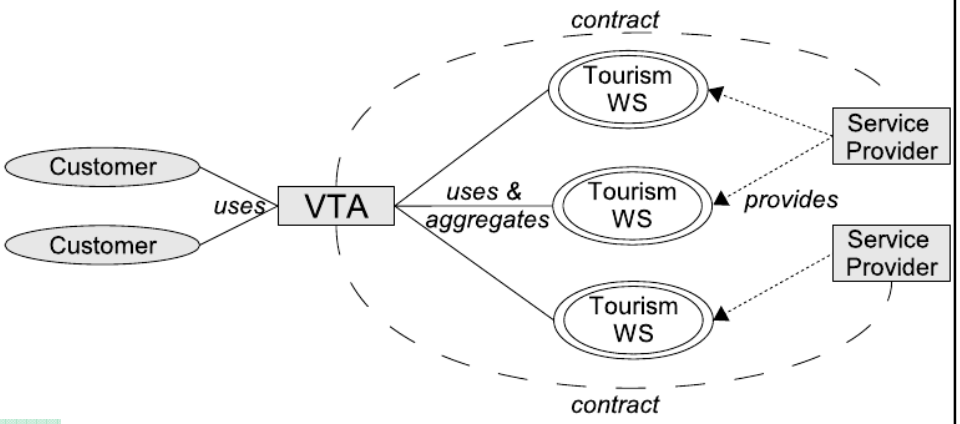
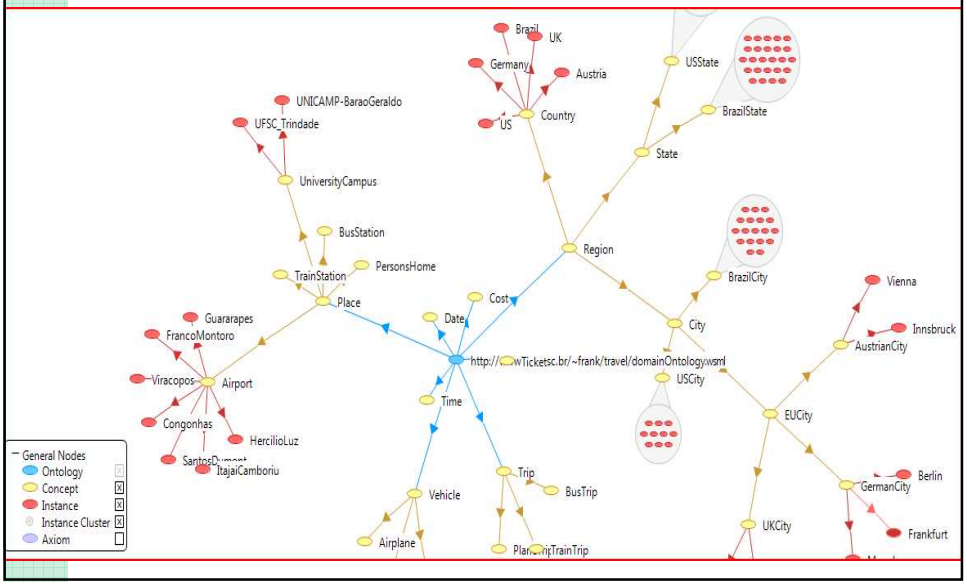
- **Case study: Travelling to SBBD**

Case Study: Virtual Travel Agency

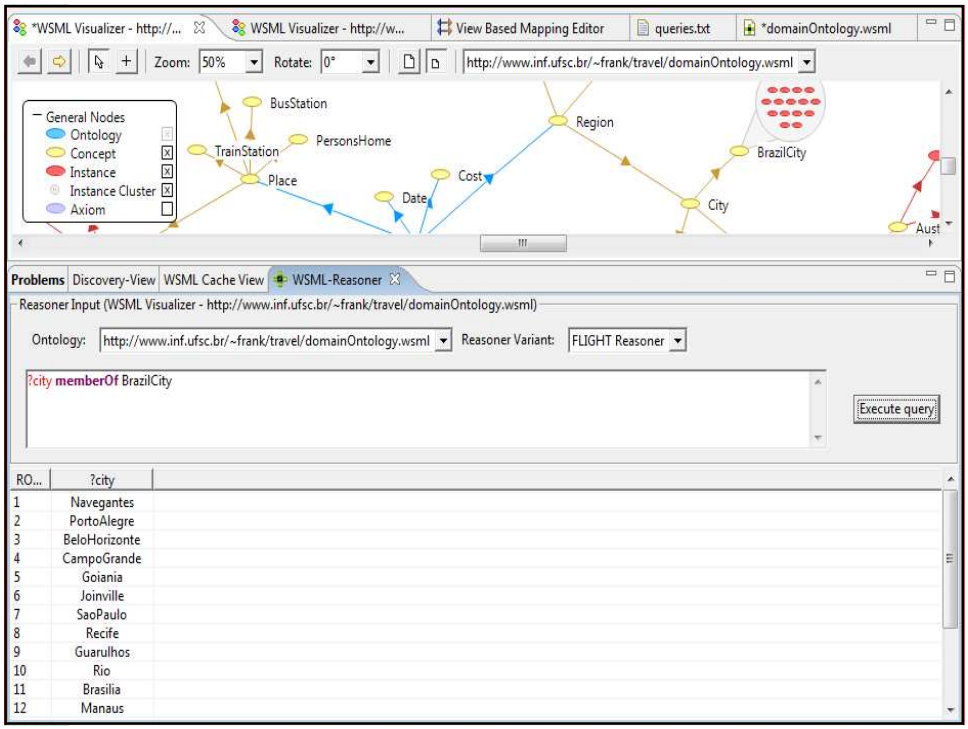


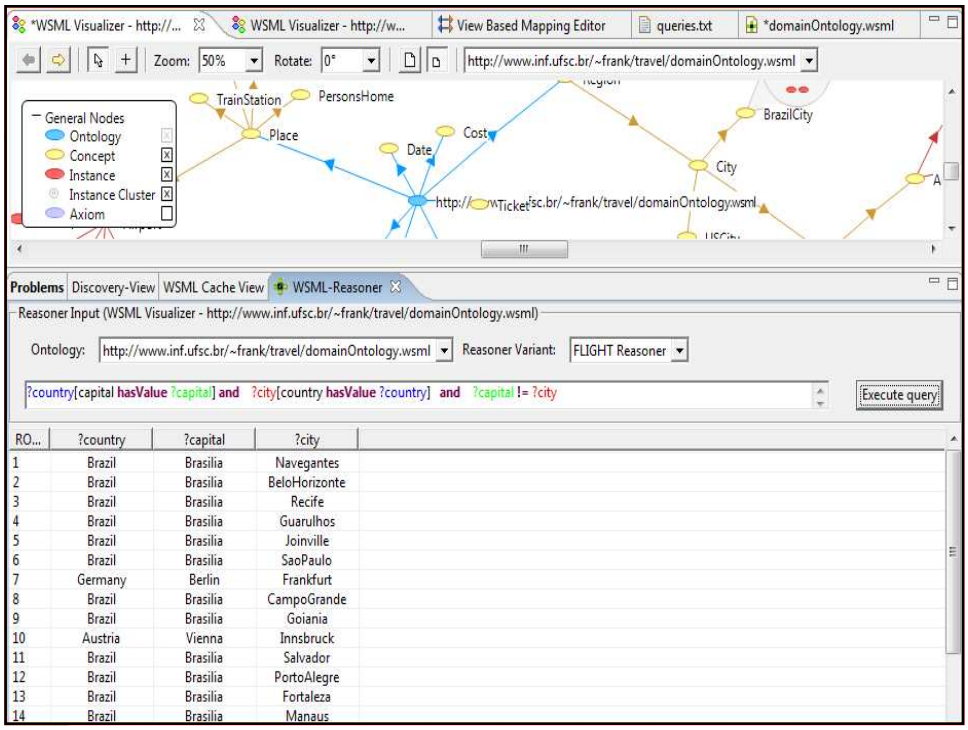
SBBD Travelling Ontology



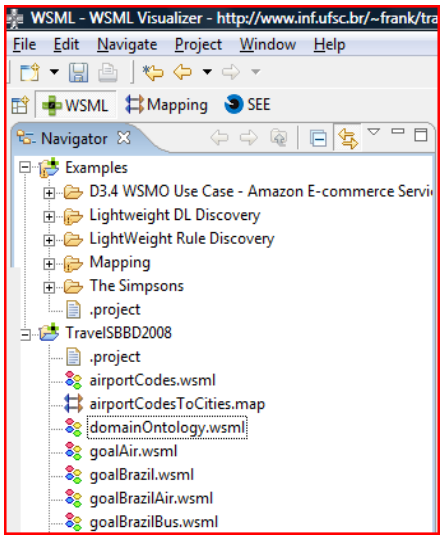
Queries

- ?city[country hasValue Brasil]
- ?city memberOf BrazilCity
- ?country[capital hasValue ?capital]
- ?country[capital hasValue ?capital] and ?capital memberOf EUCity
- ?country[capital hasValue ?capital] and ?city[country hasValue ?country] and ?capital != ?city

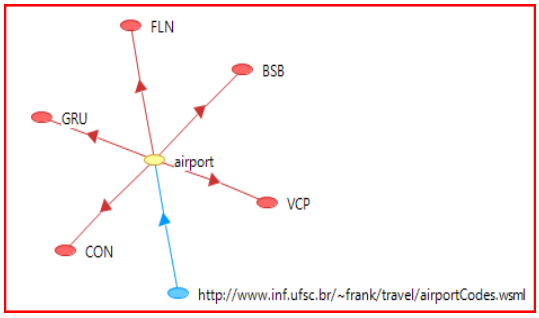




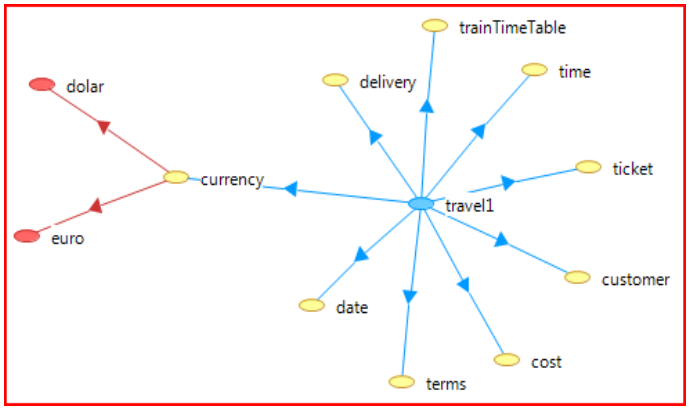
WSMT Perspectives and Navigator



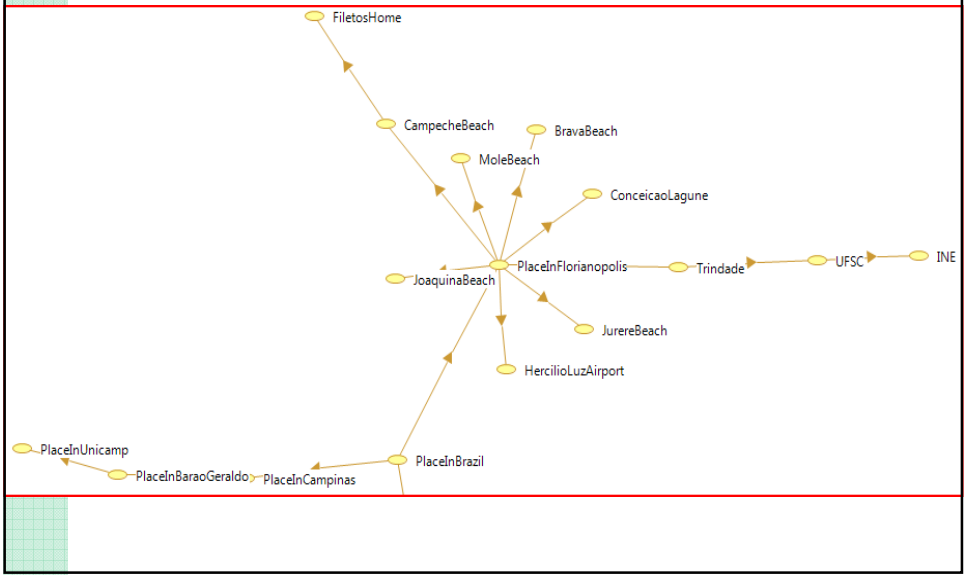
Other Travel Ontologies I



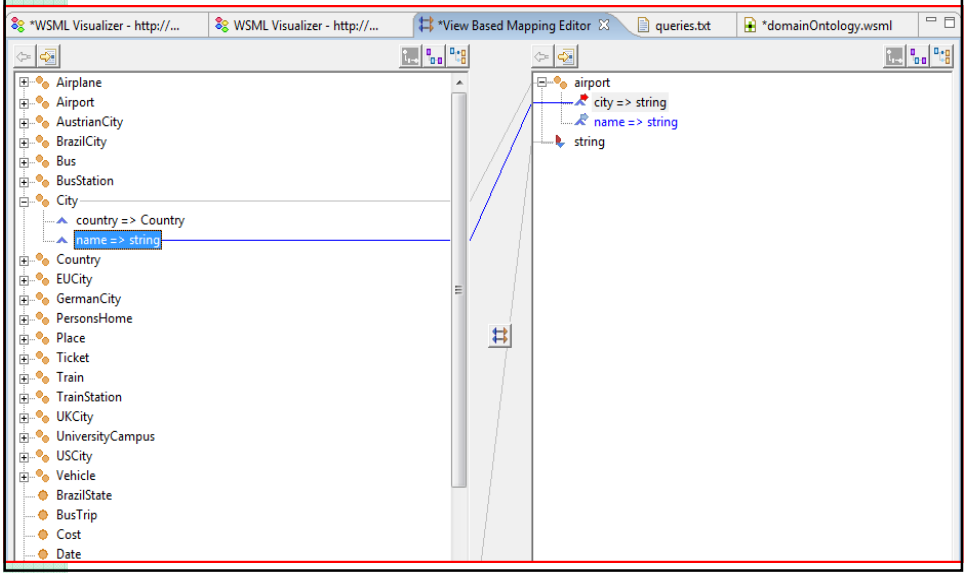
Other Travel Ontologies II



Other Travel Ontologies III



Mediation



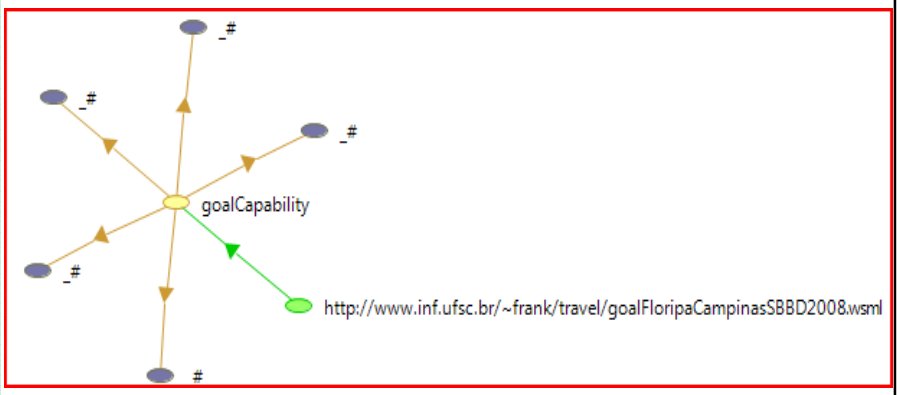
Services

Web Service BrazilAir

capability webServiceBrazilAirCapability

postcondition
definedBy
?ticket[
dO#from hasValue ?from,
dO#to hasValue ?to,
dO#vehicle hasValue ?vehicle
] memberOf dO#Ticket and
?from memberOf dO#BrazilCity and
?to memberOf dO#BrazilCity and
?vehicle memberOf dO#Airplane

Goal FLP-CPS



Goal Florianópolis-Campinas

capability goalCapability
postcondition
definedBy
?ticket[
dO#from hasValue ?from,
dO#to hasValue ?to,
dO#vehicle hasValue ?vehicle
] memberOf dO#Ticket and
?from = dO#Florianopolis and
?to = dO#Campinas.

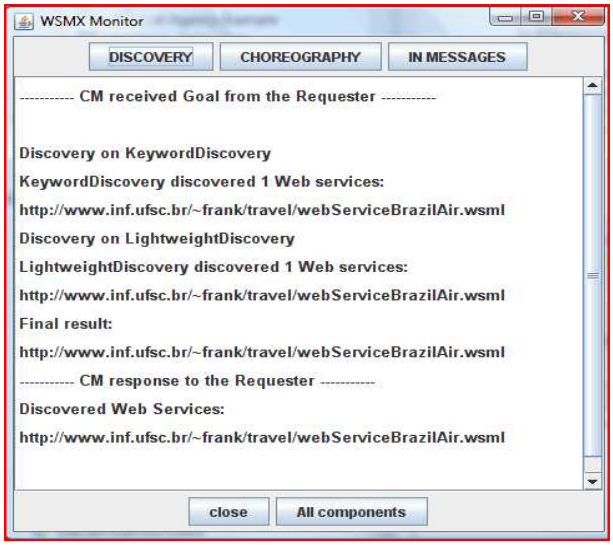
Discovered Web Services FLP-CPS

Problem!
Current WSMO version does not properly support inference on instances?

Goal BrazilAir

capability goalCapability
postcondition
definedBy
?ticket[
dO#from hasValue ?from,
dO#to hasValue ?to,
dO#vehicle hasValue ?vehicle
] memberOf dO#Ticket and
?from memberOf dO#BrazilCity and
?to memberOf dO#BrazilCity
?vehicle memberOf dO#Airplane

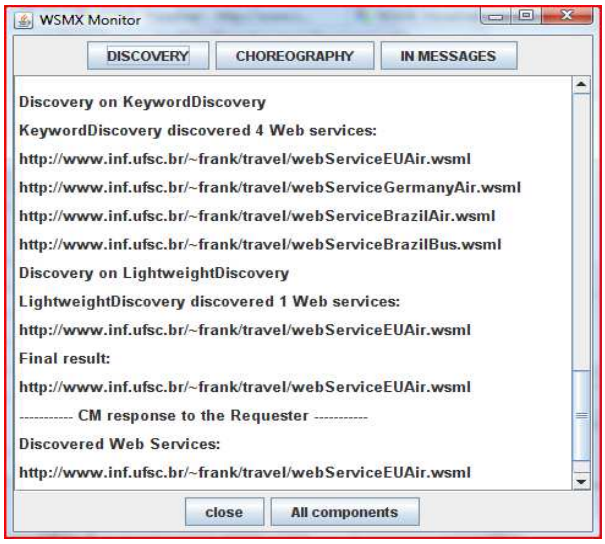
Discovered Web Services BrazilAir



Goal EUAir

capability goalCapability
postcondition
definedBy
?ticket[
dO#from hasValue ?from,
dO#to hasValue ?to,
dO#vehicle hasValue ?vehicle
] memberOf dO#Ticket and
?from memberOf dO#EUCity and
?to memberOf dO#EUCity

Discovered Web Services EUAir



Conclusions

- SWS reasearch mixes lots of theory and technology
  - Current Web services technology (WSDL, SOAP, UDDI, ...)
  - Semantic Web technology
  - Sophisticated knowledge representation and reasoning
  - Process/workflow technology (orchestration and choreography)
- Some R&D opportunities/challenges in SWS
  - Automated composition of SWS
  - Domain specific issues
  - Software tools for SWS

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Thanks all folks!

Questions?

Suggestions?

Comments?

Complaints?