Semantic Web Process Lifecycle:
Role of Semantics in Annotation,
Discovery, Composition and Execution

Invited talk: WWW 2003 Workshop on E-Services and the Semantic Web
Budapest, Hungary, Tuesday, May 20, 2003

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With Acknowledgements to METEOR-S Project team: Kaarthik Sivashanmugam, Kunal Verma, Abhijit Patil
Globalization of Processes

Workflows

Distributed Workflows

B2B

E-Services

Enterprise

Inter-Enterprise

Global

Processes driving the Networked Economy
Architectures for Web Processes*

- Process Vortex
- Process Portal
- Dynamically Trading Processes
Process Portal

Intra-enterprise Business Processes

Enterprise A

Enterprise B

WWW Catalogue

Enterprise C

WWW Catalogue

Cross-enterprise Business Processes

Processes driving the Networked Economy
Process Portal

• One-stop shopping for products or information

• A portal is responsible for carrying out or coordinating a majority of activities using the data it has and the transactions it supports.

• Predefined, (relatively) static business processes also supporting P2P interactions

A key characteristic of a portal is to own or manage much of the data and information it needs to meet its customers process needs.
Processes driving the Networked Economy
Process Vortex

- Interactions among buyers and sellers occur through governed marketplaces
- They focus on very specific product lines
- Predefined business processes
- Single interface to catalogues and supplier aggregation
Dynamically Trading Processes
Dynamically Trading Processes

- Many complex interactions among enterprises
- Business processes are highly dynamic
- Based on the needs and preferences of a customer, a virtual process is constructed on the fly to meet this very particular demand of the customer.
- Participants are a group of semi-autonomous or autonomous organizations that need to cooperate.
Processes are already becoming chief differentiating and the competitive force in doing business in the networked economy.

They are becoming the primary way to reflect the way of doing business, and that they are coming critical components of almost all types of systems supporting enterprise-level and business critical activities.
BIG Challenges

- Scalability
- Dynamic nature of business interactions
- Long duration

Hypothesis: Semantics is the most important enabler (hence Semantic Web Process)
Scalability

**Before** (Enterprise, Inter-enterprise workflows)

**Now**

Semantics of the services

Semantics of the activity (Data, Functional, Execution, QoS)

Discovery/Matchmaking should be accurate and scalable to the number of services available in Web
Dynamic Nature of Processes

- Different partners
- Different Interface for their services
- Need for dynamic partnerships
Challenges in Web Services*

- modeling, organizing collections,
- discovery and comparison,
- distribution and replication,
- access and composition,
- fulfillment (contracts, coordination versus transactions, compliance),
- quality aspects more general than correctness or precision, compliance).
- Security and trust are difficult to characterize

* From Amicalola report, Sigmod Record, Dec 2002
Contribution of Semantic Web*

- Semantic Web promises significant benefits to businesses
  - Improves productivity and efficiency
    - Reduce cost, time, effort etc.
  - Improves scalability to the size of the web
  - Exploits unique opportunities of Web
    - Converting processes from incomplete/discrete to comprehensive/continuous
    - Diversify customer base and going global
    - Volatility and dynamic nature

* From Amicalola report, Sigmod Record, Dec 2002
Semantic Web Processes: What does it provide?

- Information resource, person, organization, and many of the activities relating to them will be located on or be driven by the Web.
- Qualitatively improved interactions
- Quantitatively changes the scale and scope by automating the interactions

All this is possible only by adding “meaning” to the resources and using them for automation

* From Amicalola report, Sigmod Record, Dec 2002
SWS and SWP

Semantic Web Services*

Semantic Web Processes

* From Amicalola report, Sigmod Record, Dec 2002
(Backdrop) Industries, Technologies, Research and Vision meet at SWP

Semantic Web Process

- ebXML
- Web Services
- Workflow, EAI
- Semantic Web
Semantics for Web Processes

- Data/Information Semantics
- Functional/Operational Semantics
- QoS Semantics
- Execution Semantics
Data or Information Semantics

- **What?**
  Formal definition of data in input and output messages of a web service

- **Why?**
  Discovery and Interoperability of Web Services

- **How?**
  Annotating input/output data of web services using ontologies (METEOR-S’ WSDL-S), or formally describe I/O (DAML-S)
Function or Operational Semantics

- **What?**
  Formally representing capabilities of each web service

- **Why?**
  Discovery of Web Services

- **How?**
  Annotate operations of Web Services as well as provide preconditions and effects; Annotating TPA/SLA
Execution Semantics

- **What?**
  Formally representing the execution or flow of a services in a process or operations in a service

- **Why?**
  Analysis (verification) and validation (simulation) of the process models and exception handling

- **How?**
  Using State charts, Petri nets or activity diagrams
QoS Semantics

- **What?**
  Formally describes operational metrics of a web service/process

- **Why?**
  To select the most suitable service to carry out an activity in a process

- **How?**
  Using QoS model [Cardoso and Sheth, 2002] for web services
B2B process between Distributor and Toy Manufacturer

1. Request for details given Order on number of toys
2. Send the price and delivery details
3. Place order
4. Order confirmation

Discovery: Using data, functional and QoS semantics

Get Details (1, 2)
Place Order (3, 4)

Execution and Exception handling using QoS and Execution semantics
Discovery in Semantic Web Process Management

- An Electronic Toy distributor wants to place an order to a Toy Manufacturer

- Discovery Template
  - Functionality: What capabilities the distributor expects from the service (operational semantics)
  - Inputs: What the distributor can give to the Manufacturer’s service (data semantics)
  - Outputs: What the distributor expects as outputs from the service (data semantics)
  - QoS: Quality of Service the distributor expects from the service (QoS semantics)
Execution / Invocation

- After discovery, the service can be
  - Invoked
  OR
  - Simulated or verified if the details of the Manufacturer’s process is public
    (execution semantics)

- Verification can also be done by the Manufacturer before deploying the process
Features of Semantic Web Processes

• Different Functional and Data Semantics for competing Web services
  – ManufacturerA’s service takes order for all kind of toys
  – ManufacturerB’s service takes order specifically for electronic toys
  – ManufacturerC takes Credit card as input and produces confirmation
  – ManufacturerD takes PartnershipId as input and produces the confirmation with number of toys ordered and money that will be deducted from the account relevant to the PartnershipId given
  – ManufacturerE deals only with distributors whose credit rating is more that ‘X’
Features of Semantic Web Processes

- Selecting correct partners (Using QoS)
  - ManufacturerA delivers toys sooner but costs more
  - ManufacturerB charges more but provides takes care of delivery
  - ManufacturerC provides a service with best time and cost parameters but the failure rate is high

Which one to select for business?
Features of Semantic Web Processes

- Verification of the process (Using execution semantics)
  - ManufacturerA models his process and verifies its execution before deploying it.
  - DistributorA finds the ManufacturerB’s service, simulates its execution and if satisfied with the result invokes it.
Features of Semantic Web Processes

• Process Management (Using execution semantics)

  – Distributor wants to cancel the order when the product is about to be shipped to him. He can query the process management system if he is allowed to do that. If yes, at what penalty or cost?
• Exception handling during Process Management (Using execution semantics)
  
  – The delivery partner of the manufacturer went on strike and he needs to find an alternative delivery service.

  – How can he find an semantically equivalent alternative without compromising on the QoS of the entire process

  – If he is finding an alternative that should be compatible with the preconditions and effects of the related services in the process

  – Exception handling should be intelligent either to retry invocation of a service or by compensation action. It is difficult to hardcode/program exceptions for all possible failures
Future capabilities Semantic Web can lend to Web Processes

• Decision Making
  – Manufacturer uses trust parameters during dynamic partner selection

• Inferencing
  – Toy Distributor comes to know that all Manufacturers are going on strike. Toy manufacturer is a type of manufacturer. Hence he inferneses that he will also go on strike. So places order for toys to meet demand for toys before the strike starts.
Semantic Web Process LifeCycle

Description / Annotation
- WSDL, WSEL
- DAML-S
- Meteor-S (WSDL Annotation)

Discovery
- UDDI
- WSIL, DAML-S
- Meteor-S (P2P model of registries)

Composition / Choreography
- BPEL, BPML, WSCI, WSCL, DAML-S, METEOR-S (SCET)

Execution / Orchestration
- BPWS4J, Commercial BPEL Execution Engines, Intalio n3, HP eFlow

Data / Information Semantics
Semantic Web Process LifeCycle

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Execution / Orchestration

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**Execution Semantics**
**Semantic Web Process LifeCycle**

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**QoS Semantics**
- Functional / Operational Semantics

**Discovery**
- UDDI
- WSIL, DAML-S
- Meteor-S (P2P model of registries)
• Applying Semantics in Annotation, Quality of Service, Discovery, Composition, Execution

• Focuses on two issues: semantic Web services and process composition.

• Process Composition:
  • Functional perspective
    – Web Service Discovery, handling semantic heterogeneity
  • Operational perspective
    – QoS specification for Web Services and Processes.
• **Discovery Infrastructure (MWSDI)**
  - Semantic Annotation of Web Services
  - Semantic Peer-to-Peer network of Web Services Registries

• **Composer**
  - SCET: Service Composition and Execution Tool
  - Semantics Process Template Builder (under development)

• **QoS Management**
  - Specify, compute, monitor and control QoS (SWR algorithm)

• **Orchestrator**
  - Analysis and Simulation
  - Execution
  - Monitoring
Semantics in METEOR-S

METEOR-S examples of using/supporting semantics:
- Annotation
- Discovery
- Composition (in development)
- QoS
MWSDI : Annotation
Present Discovery Mechanism

- **UDDI**: Keyword, taxonomy based search
  - Example: “Quote”
    - Microsoft UBR returned 12 services
    - Human reading of description (Natural Language) help me understand:
      - 6 Entries are to get Famous Quotes
      - 1 Entry for personal auto and homeowners quoting
      - 1 Entry for multiple supplier quotes on all building materials
    - Categorization suggested for UDDI is useful but inadequate (what does the WS do?):
      - 1 Entry for Automobile Manufacturing
      - 1 Entry for Insurance agents, brokers, & service
    - Alternatively read and try to understand WSDL
      - 1 Entry related to security details (Human Understanding)
      - 1 Test Web service for Quotes (which quote?)
Simplest Example

- http://www.reluctantdba.com/webquotes/WebQuotes.asmx
- GetQuote, GetQuoteById, GetQuoteForPerson ...
  - Which one is suitable?
  - What does the signature mean?
    - `<XS:ComplexType>:Quote GetQuote (String UserName, String Password, int QuoteType) ;; what is a QuoteType?
  - Which interaction is suitable?
    - New users 1. Register 2. Confirm 3. GetQuote()
    - Existing users 1. GetQuote()
    - Confirm: “This method is used to confirm your email address”. WSDL says input message part name is “UserGUID” of type “string”. What is this part?
  - What are the restrictions for service invocation
    - “RegisterUser method is used to register to use WebQuotes. You won't be able to start using WebQuotes until we have confirmed your email address.”
    - Solution: Precondition and effects
Another WSDL

- GetRandomQuote
  - Description: “Returns a random quote, as GetRandomQuote, but this time just German ones.”
  - How do we (user, programmer, software agent) understand this?

- It does not have the same interface specification as the previous one. Which one is suitable to my application?

- With the same signature, how is GetRandomQuote different from GetJoke operation (both return complex type):
  http://www.interpressfact.net/webservices/getJoke.asmx
Out of these results, some do not have formal WSDL implementation, some links are not working and it does not return all the results.

Patil, Oundhakar, Sheth, SAWS Technical Report
Can Semantic Annotation of Web Services help?

<table>
<thead>
<tr>
<th>Service</th>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>FastWeather</td>
<td>WMO code (string)</td>
<td>Weather</td>
</tr>
<tr>
<td>GlobalWeather</td>
<td>WMO/ICAO code (string)</td>
<td>Weather</td>
</tr>
<tr>
<td>WorldWeather</td>
<td>WMO code (string)</td>
<td>Array of Strings</td>
</tr>
<tr>
<td>FetchWeather</td>
<td>Zip Code (string)</td>
<td>Weather</td>
</tr>
</tbody>
</table>

Patil, Oundhakar, Sheth, SAWS Techinal Report
How to Annotate?

- Map Web service’s input & output data as well as functional description using relevant data and function/operation ontologies, respectively.

- How?
  - Borrow from schema matching
  - Semantic disambiguation between terms in XML messages represented in WSDL and concepts in ontology.
Semantic Annotation: Data Semantics

```
<xsd:complexType name="Wind">
  <xsd:sequence>
    <xsd:element name="prevailing_speed" type="xsd:double" />
    <xsd:element name="gust_speed" type="xsd:double" />
    <xsd:element name="prevailing_direction" type="xsd1:Direction" />
  </xsd:sequence>
</xsd:complexType>

<xsd:complexType name="Pressure">
  <xsd:sequence>
    <xsd:element name="altimeter" type="xsd:double" />
    <xsd:element name="slp" type="xsd:double" />
    <xsd:element name="delta" type="xsd:double" />
  </xsd:sequence>
</xsd:complexType>
```

<table>
<thead>
<tr>
<th>WindEvent</th>
<th>WindEvent</th>
<th>WindEvent</th>
<th>PressureEvent</th>
<th>PressureChangeEvent</th>
</tr>
</thead>
<tbody>
<tr>
<td>windDirection</td>
<td>windSpeed</td>
<td>windGustSpeed</td>
<td>AltimeterSetting</td>
<td>SeaLevelPressure</td>
</tr>
</tbody>
</table>

Ontology: weather-ont.daml
WSDL: GlobalWeather.wsdl

Patil, Oundhakar, Sheth, SAWS Technical Report
Semantic Annotation: Functional Semantics

WSDL Operations

Patil, Oundhakar, Sheth, SAWS Technical Report
Semantic Annotation

- **IOParametersMatch** \((w,o) =\)
  
  \[
  \text{LinguisticMatch} (w,o) + \text{StructureMatch} (w,o) + \text{ContextMatch} (w,o)
  \]

- **LinguisticMatch** \((w,o) \Rightarrow\)
  
  - NameMatch
  - SynonymsMatch
  - **HypernymRelation** \((w \text{ is a kind of } o)\)
  - **HyponymRelation** \((o \text{ is a kind of } w)\)

- **StructureMatch** \((w,o) \Rightarrow\)
  
  - \(\text{subTree}(w) == \text{subTree}(o)\)

- **ContextMatch**
  
  - Name of the parent concept provides some insight to the context of the term
IOParametersMatch \((w, o)\) =
\[
\frac{w_1 \cdot \text{LinguisticMatch} \,(w, o) + w_2 \cdot \text{StructureMatch} \,(w, o) + w_3 \cdot \text{ContextMatch} \,(w, o)}{w_1 + w_2 + w_3}
\]

- Weights \(w_1, w_2\) and \(w_3\) can be decided by the user based on the confidence in the respective type of matching technique.
- LinguisticMatch uses a SynonymDictionary, also uses WordNet.

StructureMatch \((w, o)\) =
\[
\begin{align*}
& / \quad \text{LinguisticMatch}(w, o) \quad \text{if} \quad o \in O.\text{subclasses} \\
& \max < \\
& \quad \sqrt{\text{LinguisticMatch}(w, o) \cdot \text{RangeMatch}(w, o)} \quad \text{if} \quad o \in O.\text{properties}
\end{align*}
\]
METEOR-S Discovery
State of the art in discovery

UDDI Business Registry is universal and provides non-semantic search

Search retrieves lot of services (irrelevant results included)

- Which service to select?
- How to select?
Registries are categorized

Select relevant registries
(semantic filtering)

Select service(s) of interest

Registry is domain specific and supports semantic search
MWSDI details

- Large number of registry/repository implementations are anticipated [NIST report]. (how to link all registries ?)

- Scalable environment for **Web Service Discovery**
  - Scalability using p2p network of registries
  - improved quality of discovery using Semantic Annotation

- Implemented JXTA based p2p network of UDDI & Peer Roles

- Peer interaction protocols implementation
  - Registry addition to the registry community
  - Publishing a Web Service with annotation
  - Semantic discovery of Web Services

- Ontology (Registries Ontology) based Registry selection for querying the registry
QoS in METEOR-S
QoS Management

- End-to-End process analysis
- QoS management is indispensable for organizations striving to achieve a higher degree of competitiveness.
- Based on previous studies* and our experience with business processes, we have constructed a QoS model composed of the following dimensions:
  - Time
  - Cost
  - Reliability
  - Fidelity

*Stalk and Hout, 1990; Rommel et al., 1995; Garvin, 1988
Research Issues in QoS

• **Specification.** What dimensions need to be part of the QoS model for processes?

✓ • **Computation.** What methods and algorithms can be used to compute, analyze, and predict QoS?

✓ • **Monitoring.** What kind of QoS monitoring tools need to be developed?

✓ • **Control.** What mechanisms need to be developed to control processes, in response to unsatisfactory QoS metrics?
QoS in METEOR-S

SWR algorithm
QoS Computation
Simulation
Log

QoS Model

QoS Estimates for Tasks/Web services

QoS Estimates for Transitions

Stochastic Process
Enact

Design

Jorge Cardoso, PhD Thesis, 2002
Composition

• SCET (Web Processes, no semantics)
  – Static composition and centralized execution

• Semantic Process Template Builder (under development)
  – Improved Discovery Mechanism
    • Uses Data/Operational and QoS Semantics in Service Discovery
  – Template Based Process Designer, Generic Web Process Template and support for any executable process specification standard
Broad Scope of Semantic (Web) Technology

Current Semantic Web Focus

Lots of Useful Semantic Technology (interoperability, Integration)

Other dimensions: how agreements are reached, ...

Scope of Agreement

Degree of Agreement

agreement about

Qos
Execution
Function
Data/Info.
Common Sense
Gen. Purpose, Broad Based
Domain Industry
Task/App
Formal
Semi-Formal
Informal
Conclusion

- Semantics can help address big challenges related to scalability, dynamic environments,..
- But comprehensive approach to semantics will be needed:
  - Data/information, function/operation, execution, QoS
- Semantic (Web) principles and technology bring new tools and capabilities that we did not have in EAI, workflow management of the past

More at: http://swp.semanticweb.org, or http://lsdis.cs.uga.edu/SWP.htm
Also, Talk Abstract