Semantic Web Progress and Directions

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Semantic Web Perspectives

- The Semantic Web means different things to different people. It is multi-dimensional
  - Distributed data access
  - Inference
  - Data Integration
  - Logic
  - Services
  - Search (based on term meaning)
  - Configuration
  - Agents
  - …

- Different users value these dimensions differently

- Theme: Machine-operational declarative specification of the meaning of terms
Semantic Web Layers

Ontology Level

- Languages (CLASSIC, DAML-ONT, DAML+OIL, OWL, IKL, …)
- Environments (FindUR, Chimaera, OntoBuilder/Server, Sandpiper Tools, …)
- Services (OWL-S, SWSL, Wine Agent, Explainable SDS, …)
- Standards (NAPLPS, …, W3C’s OWL, W3C’s Semantic Web Best Practices, EU/US Joint Committee, OMG ODM, …)

Rules: SWRL, RIF (previously CLASSIC Rules, explanation environment, extensibility issues, contracts, …)

Logic: Description Logics, FOL, …

Proof: PML, Inference Web Services and Infrastructure

Trust: IWebTrust, …

http://www.w3.org/2004/Talks/0412-RDF-functions/slide4-0.html

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Semantic Web Progress from a W3C perspective

- Semantic Web foundation specifications in recommendation status: RDF, RDF Schema, and OWL

- OWL Specs available from WebOnt working group page:
  

  Best starting points: OWL Overview and OWL Guide

- Working Group Conclusion: RDF and OWL are Semantic Web standards that provide a framework for asset management, enterprise integration and the sharing and reuse of data on the Web.

- Press Release - [http://www.w3.org/2004/01/sws-pressrelease](http://www.w3.org/2004/01/sws-pressrelease)

- Testimonials from a number of companies
  
  [http://www.w3.org/2004/01/sws-testimonial](http://www.w3.org/2004/01/sws-testimonial)

- WebOnt has completed as a working group

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W3C Standards view continued

- Best Practices working group [www.w3.org/2001/sw/BestPractices/](http://www.w3.org/2001/sw/BestPractices/) (completed but follow-on working group started)

- Task forces on:
  - Ontology Engineering and Patterns - [http://www.w3.org/2001/sw/BestPractices/OEP/](http://www.w3.org/2001/sw/BestPractices/OEP/) Example – representing classes as property values, semantic integration, n-ary relations, …
  - Porting Thesauri - [http://www.w3.org/2004/03/thes-tf/mission](http://www.w3.org/2004/03/thes-tf/mission) - SKOS - Simple Knowledge organization System
W3C Best Practices, continued

  
  Note on ODA and potential uses of the Semantic Web in Systems and SW engineering

  
  E.g. best practice recipes for publishing RDF vocabularies

W3C Semantic Web Deployment Working Group

http://www.w3.org/2006/07/SWD/

The mission of this Working Group is to provide guidance in the form of W3C Technical Reports on issues of practical RDF development and deployment practices in the areas of publishing vocabularies, OWL usage, and integrating RDF with HTML documents.

- Best Practice Recipes for Publishing RDF Vocabularies
- RDF/A Primer 1.0; Embedding RDF in XHTML
- SKOS Core Vocabulary Specification, SKOS Core Guide
- Metainformation Module and Metainformation Attributes Module of XHTML 2.0
- Planning - Principles of Good Practice for Managing RDF Schemas and OWL Ontologies Working Draft (February)

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Some Operational Results of Recommendation Status

- Tools options and depth are expanding
  - Browsers, editors, reasoners, etc
  - Open Source options (e.g., Protégé, SWOOD, PELLET, JTP, Chimaera, Inference Web, …)
  - Industrial supported options (e.g., Sandpiper, TopQuadrant, Cerebra (acquired by WebMethods), …)
  - Funded research programs expand for research (largely in Europe) and for application areas in US (e.g., NIH CBio, DARPA PAL**, DARPA Integrated Learning, DTO NIMD, DTO IKRIS, …)
  - Interest in other areas – e.g., NASA’s Semantic Web Roadmap, NSF’s Cybertrust programs, scientific data integration, etc.
  - Active community – ISWC, ESWC, OWL Directions, SWUI, etc.
- Look at ISWC in November for status

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Rules (SWRL to RIF)

■ SWRL – Semantic web Rule Language combining OWL and RuleML
  ● Submitted to W3C http://www.w3.org/Submission/2004/03/

■ W3C Workshop on Rule Languages for Interoperability  April 2005
  ● http://www.w3.org/2004/12/rules-ws/
  ● Identified 7 candidate technologies: WSML, RuleML, SWSL, N3, SWRL, Common Logic, TRIPLE
  ● Identified driving use cases

■ Rule interchange Working Group (RIF) formed chaired by ibm and ilog  - http://www.w3.org/2005/rules/wg
  ● Dec 2005 burlingame – kickoff
  ● Feb 2006 france – use cases, design goals,
  ● June 2006 – montenegro,
  ● Coming up nov 2006 - iswc
RIF: continued

- Wiki one of the best places to monitor - http://www.w3.org/2005/rules/wg/wiki/

- Deliverables  Working Draft of "RIF Use Cases and Requirements" , Second Public Working Draft of "RIF Use Cases and Requirements" , UCR (working version of the Use Cases and Requirements draft)

- CORE  - core design for a format that allows rules to be translated between rule languages and thus transferred between rule systems.

- Task Areas: Design Principles and Design Constraints , Use Cases , Rulesystem Arrangement Framework (aka RIF-RAF) , OWL Compatibility and RDF Compatibility , Extensible Design, Outreach

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Semantic Web Health Care and Life Sciences Interest Group

- Community of Interest – designed to improve collaboration, research and development, and innovation adoption in the health care and life sciences industries…. Will bridge many forms of biological and medical information across institutions
  - http://www.w3.org/2001/sw/hcls/

- First F2F meeting – Jan 2006 - >60 attendees
  www.w3.org/2001/sw/hcls/f2f-2006/f2f-summary.html
  - 6 task forces emerge

- Other communities of practice under investigation… possibly the petroleum industry.. Norwegian Semantic Web days in April. Continuation of work connecting process standards and semantic web technology.
Semantic Web for Health and Life Sciences Task Forces

- Structured Data to RDF
  [http://esw.w3.org/topic/BioRDF_Charter](http://esw.w3.org/topic/BioRDF_Charter)

- Text to Structured Data
  [www.ccs.neu.edu/home/futrelle/W3C-HCLSig/group-report-draft26Jan06.html](http://www.ccs.neu.edu/home/futrelle/W3C-HCLSig/group-report-draft26Jan06.html)

- Knowledge Life Cycle
  [www.w3.org/2001/sw/hcls/task_forces/Knowledge_Ecosystem.html](http://www.w3.org/2001/sw/hcls/task_forces/Knowledge_Ecosystem.html)

- Ontologies working group
  [esw.w3.org/topic/HCLLS/OntologyTaskForce](http://esw.w3.org/topic/HCLLS/OntologyTaskForce)

- Adaptive Healthcare Protocols and Pathways
  [esw.w3.org/topic/HclsigDiscussionTopics/HclsSubGroupACPP](http://esw.w3.org/topic/HclsigDiscussionTopics/HclsSubGroupACPP)

- ROI Analysis within HCLS
Services

- OWL-S came out of the DAML program as an ontology for web services - [http://www.daml.org/services/owl-s/](http://www.daml.org/services/owl-s/)

- Version 1.2 available - [http://www.daml.org/services/owl-s/1.2/](http://www.daml.org/services/owl-s/1.2/)

- Submitted to W3C as a member submission – nov 2004 [http://www.w3.org/Submission/OWL-S/](http://www.w3.org/Submission/OWL-S/)

- Broadened to be more expressive and submitted to W3C
  - [http://www.w3.org/Submission/2005/07/](http://www.w3.org/Submission/2005/07/)
  - SWSF – Semantic Web Services Framework
  - SWSL – Semantic Web Services Language
  - SWSO – Semantic Web Services Ontology
  - SWSF Application Scenarios
Services, cont.

- Web Service Modeling Ontology submitted to W3C April 2005
  - http://www.w3.org/Submission/2005/06/
  - WSMO Web Service Modeling Ontology
  - WSML – Web Service Modeling Language
  - WSMX – Web Service Execution Environment (WSMX)

- WSDL-S Web Service Semantics submitted Nov 2005

- Semantic Web Services Interest Group formed:
  http://www.w3.org/2002/ws/swsig/

- June 2005 Meeting held in Innsbruck
  http://www.w3.org/2005/04/FSWS/program.html
Web Services Description Language WG


- “The objective … is to develop a mechanism to enable annotation of Web services descriptions. This mechanism will take advantage of the WSDL 2.0 extension mechanisms to build a simple and generic support for semantics in Web services.”

- Telecons started in April, F2f meeting in June in galway

- 2 drafts listed – semantic annotations for WSDL and usage doc.

- This document defines a set of extension attributes for the Web Services Description Language [WSDL 2.0] that allow to describe additional semantics of WSDL components. The specification defines how such semantic annotation is accomplished using references to semantic models, e.g. ontologies. SAWSDL does not specify a language for representing the semantic models. Instead it provides mechanisms by which concepts from the semantic models, typically defined outside the WSDL document, can be referenced from within WSDL components using annotations.
Other Semantic Web Stack Layers

- Proof and Trust do not currently have interest or working groups
- Active work in progress…
- Inference Web and related work provides tool sets for manipulating, browsing, summarizing, presenting, combining, checking, validating, searching, etc. PML
- IW Trust – a trust representation and propagation framework for providing trust information
- Applications like integration of scientific data – NASA, NSF, NCAR, …
Framework for explaining question answering tasks by
- abstracting, storing, exchanging,
- combining, annotating, filtering, segmenting,
- comparing, and rendering proofs and proof fragments
provided by question answerers.

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Example Semantic Web Usage – Cognitive Assistant that Learns and Organizes

- DARPA IPTO funded program

- Personal office assistant, tasked with:
  - Noticing things in the cyber and physical environments
  - Aggregating what it notices, thinks, and does
  - Executing, adding/deleting, suspending/resuming tasks
  - Planning to achieve abstract objectives
  - Anticipating things it may be called upon to do or respond to
  - Interacting with the user
  - Adapting its behavior in response to past experience, user guidance

- Contributed to by 22 different organizations

- End of year 3 of 5 year program
Architecture for Explaining Task Processing

Collaboration Agent

Explanation Dispatcher

TaskLearner1
TaskLearner2
TaskLearner3

Task Manager (TM)

TM Explainer

TM Wrapper

Justification Generator

Task State Database
Task Explanation - sample prototype for Command Post of the Future (Stanford, SRI)

- Explanations of end-to-end task processing
- Initial dialog (limited follow-up capability)
- PML representation for complex tasks
- Design in process for explaining learned task modifications

Initial explanation, with links indicating follow-up queries (why haven’t you completed xxx) and alternate strategies.
Discussion

- Semantic Web infrastructure has reached recommendation status for the foundation
- Active working groups or interest groups on Rules and Services in addition to best practices
- Research in other areas of Semantic Web stack mature enough for usage, e.g., explanation
- Open source and commercial tools are emerging
- Growing number of example implemented use cases available
- Outreach – into science domains in particular – NIH, AGU, grid, etc.
How PML Works

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Explainer Strategy (for cognitive assistants)

Present

- Query
- Answer
- Abstraction of justification (using PML encodings)
- Provide access to meta information
- Suggests drill down options (also provides feedback options)
An InferenceWeb Primer

1. Registry and service support for knowledge provenance.
2. Language for encoding hybrid, distributed proof fragments (both formal and informal).
3. Declarative inference rule representation for checking proofs.
4. Multiple strategies for proof abstraction, presentation, and interaction.

Framework for explaining reasoning and execution tasks by abstracting, storing, exchanging, combining, annotating, filtering, comparing, and rendering justifications from varied cognitive reasoners.
Proof Markup Language (PML) is a proof interlingua

Used to represent justification of information manipulation steps done by theorem provers, extractors, other reasoners

Main components concern inference representation and provenance issues

Specification written in OWL

http://foo.com/Example.owl#Laptop

iw:NodeSet
iw:isConsequenceOf
iw:InferenceStep
iw:hasRule: SupportsTopLevelGoal
iw:hasSourceUsage: TailorComment
iw:hasEngine: SPARK
iw:hasConclusion: (Supports GA BL)
iw:hasLanguage: KIF
NodeSet: Executing(GS)

SupportsTopLevelGoal(x) & IntentionPreconditionMet(x) & TerminationConditionNotMet(x) => Executing(x)

TopLevelGoal(y) & Supports(x,y) => SupportsTopLevelGoal(x)

ParentOf (x,y) & Supports(y,z) => Supports (x,z)

Supports (x,x)

GS: GetSignature
BL: BuyLaptop
GA: GetApproval
Producing Explanations

- Dialogue starts with any of several supported **questions types**

- ICEE chooses a **strategy**: an approach for abstracting the formal justification, depending on:
  - User model
  - Context

- Justification is parsed to present portions relevant to query and strategy

- ICEE suggests **follow-up queries** to enable mixed initiative dialogue
Explanation Example

Sample question type: task motivation

Why are you doing <subtask>?

Strategy: reveal task hierarchy

I am trying to do <high-level-task> and <subtask> is one subgoal in the process.

Alternate strategies:

- Provide task abstraction
- Expose preconditions
- Expose termination conditions
- Reveal meta-information about task dependencies
- Explain provenance related to task preconditions or other knowledge
Follow-up questions

- Request additional **detail**
- Request **clarification** of the given explanation
- Request an **alternate strategy** to the original query

Sample Interface Linked to ICEE

Initial explanation, with links indicating follow-up queries and alternate strategies.
Advantages to ICEE Approach

- **Unified framework** for explaining task execution and deductive reasoning exploiting semantic web technologies.

- Architecture for reuse among many task execution systems.

- **Introspective predicates** and software wrapper that extract explanation-relevant information from task reasoner.

- Reusable **action schema** for representing task reasoning.

- A version of InferenceWeb for generating formal justifications.
Wine Agent receives a meal description and retrieves a selection of matching wines available on the Web, using an ensemble of emerging standards and tools:

- DAML+OIL / OWL for representing a domain ontology of foods, wines, their properties, and relationships between them
- JTP theorem prover for deriving appropriate pairings
- OWL-QL for querying a knowledge base consisting of the above
- Inference Web for explaining and validating the response
- [Web Services for interfacing with vendors]
- Utilities for conducting and caching the above transactions
KSL Wine Agent 1.0

How does it work?

Please select a type of course:

**SEAFOOD**
- Fish:
  - Blowfish
  - Flounder

**RED MEAT**
- Regular red meat
- Spicy red meat

**WHITE MEAT**
- Light-meat fowl
- Dark-meat fowl

**PASTA**
- Pasta w/ regular red sauce
- Pasta w/ spicy red sauce
- Pasta w/ light cream sauce
- Pasta w/ heavy cream sauce

**DESSERT**
- Sweets
- Nuts and cheese

**FRUIT**
- Sweet fruit
- Unsweet fruit

**TOMATO-BASED FOOD**

Or, select a specific item from the sample menu:

**Starters:**
- Dozen clams
- Dozen oysters
- Dozen mussels
- Personal cheese pizza

**Poultry:**
- Rotisserie chicken
- Roast duck
- Roast goose
- Roast turkey

**Meat:**
- Grilled T-Bone steak
- 10 oz.
- Prime rib
- Garlicky roast beef tenderloin
- Grilled veal
- Grilled pork chops
- Lamb curry

**Pasta:**
- Spaghetti with tomato sauce
- Fetuccine Alfredo
- Fra Diavolo
- Linguine with white clam sauce

**Seafood:**
- Grilled tuna
- Broiled flounder
- Grilled swordfish
- Grilled halibut
- Broiled scrod
- Maine lobster
- Whole Dungeness crab

**Dessert:**
- Double chocolate cake
- Apple pie
- Fruit plate
- Baked apples
- Bananas Foster
- Peach cobbler
- Assorted nuts
- Assorted cheeses

Comments appreciated.

Last modified: Tue Apr 1 11:30:31 PST 2003
<rdfs:Class rdf:ID="BLAND-FISH-COURSE">
  <daml:intersectionOf rdf:parseType="daml:collection">
    <rdfs:Class rdf:about="#MEAL-COURSE"/>
    <daml:Restriction>
      <daml:onProperty rdf:resource="#FOOD"/>
      <daml:toClass rdf:resource="#BLAND-FISH"/>
    </daml:Restriction>
  </daml:intersectionOf>
  <rdfs:subClassOf rdf:resource="#DRINK-HAS-DELICATE-FLAVOR-RESTRICTION"/>
</rdfs:Class>

<rdfs:Class rdf:ID="BLAND-FISH">
  <rdfs:subClassOf rdf:resource="#FISH"/>
  <daml:disjointWith rdf:resource="#NON-BLAND-FISH"/>
</rdfs:Class>

<rdf:Description rdf:ID="FLOUNDER">
  <rdf:type rdf:resource="#BLAND-FISH"/>
</rdf:Description>

<rdfs:Class rdf:ID="CHARDONNAY">
  <rdfs:subClassOf rdf:resource="#WHITE-COLOR-RESTRICTION"/>
  <rdfs:subClassOf rdf:resource="#MEDIUM-OR-FULL-BODY-RESTRICTION"/>
</rdfs:Class>

<rdfs:Class rdf:ID="MODERATE-OR-STRONG-FLAVOR-RESTRICTION"> [...]</rdfs:Class>
Processing

Given a description of a meal,

- Use OWL-QL to state a premise (the meal) and query the knowledge base for a suggestion for a wine description or set of instances
- Use JTP to deduce answers (and proofs)
- Use Inference Web to explain results (descriptions, instances, provenance, reasoning engines, etc.)
- Access relevant web sites (wine.com, ...) to access current information
- Use OWL-S for markup and protocol*

Course Type: PASTA-WITH-NON-SPICY-RED-SAUCE

"Pairs well with dry red varieties. Medium-bodied wines featuring moderate flavors match especially well."

The local knowledge base particularly recommends the following:

- MARIETTA PETITE SYRAH
- SAUCELITO CANYON ZINFANDEL
- MARIETTA ZINFANDEL
- PAGE MILL WINERY CABERNET SAUVIGNON
- GARY FARRELL MERLOT
- MARIETTA CABERNET SAUVIGNON
- CHIANTI CLASSICO
- MOUNTADAM PINOT NOIR
- MARIETTA OLD VINES RED
- WHITEHALL LANE CABERNET FRANC

The recommended wines can be found below, along with some comparable selections:

Web Inventory Search

Alternatively, the following varieties include many suitable matches:

- PINOT-NOIR
- MERLOT
- RED-BORDEAUX

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Ontology: WINES

- **Name:** Wines Ontology
- **URL:**
- **Description:** The CLASSIC Wines knowledge base translated into Ontolingua and then into DAML+OIL
- **Source(s):**
  - **Name:** Deborah L. McGuinness
  - **Organization(s):**
    - **Name:** Knowledge Systems Laboratory, Stanford University
    - **URL:** [http://www.KSL.Stanford.EDU](http://www.KSL.Stanford.EDU)
- **Version:** 2000-12-01
Wine Agent 1.0

How does it work?

The following wines were found across the web...

- MOUNTADAM PINOT NOIR at Wine.com
- PAGE MILL WINERY CABERNET SAUVIGNON at Wine.com
- CHIANTI CLASSICO at Wine.com
- CHIANTI CLASSICO at Wine Commune
- MARIETTA PETITE SYRAH at Wine.com
- WHITEHALL LANE CABERNET FRANC at Wine.com
- MARIETTA CABERNET SAUVIGNON at Wine.com
- MARIETTA ZINFANDEL at Wine.com
- FORMAN CABERNET SAUVIGNON at Wine.com
- FORMAN CABERNET SAUVIGNON at Wine Commune
- SAUCELITO CANYON ZINFANDEL at Wine.com
- GARY FARRELL MERLOT at Wine.com
- GARY FARRELL MERLOT at Wine Commune
- MARIETTA OLD VINES RED at Wine.com
- KATHRYN KENNEDY LATERAL at Wine.com
Explainable Semantic Discovery Service

Semantic Discovery Service (SDS) is a union of the industry process-modeling standard Business Process Execution Language for Web Services (BPEL4WS) with the OWL-based Web Service Ontology (OWL-S) and associated Semantic Web reasoning machinery to perform:

- Dynamic service binding of BPEL4WS Web service compositions based on user’s personal preferences and constraints
- Semantic translation to enable interoperability between disparate services.

We’ve integrated SDS with the Inference Web explanation toolkit to:

- Provide solutions that are transparent and explainable
- Pave the way for rich interaction between user and system in mixed-initiative Web service composition.
- Address issues of trust related to the automation of Web service tasks
- Provide an infrastructure for audits
**Semantic Discovery Service (SDS)**

- Motivated by long-term goal of seamless interoperation between networked programs and devices

- Integrates Semantic Web technologies with industrial infrastructure
  - BPEL4WS (BPEL) - Business process language to orchestrate interactions between Web services. (IBM, Microsoft, BEA, SAP, etc.)
    - Enables **manual** composition of Web services using process modeling
    - Lacks rich data types and class relationships necessary to automate discovery and integration of Semantic Web services
  - SDS - Serves as a proxy between BPEL engine and potential service partners to enable dynamic discovery and integration
    - **Proxy for BPEL engine:** BPEL invokes SDS with:
      - Functional and user-defined non-functional restrictions encoded in OWL-S
      - Invocation parameters to pass to discovered service
    - **Automated service customization:** SDS uses the OWL Query Language (OWL-QL) to query a KB of OWL-S service descriptions for a matching service. Queries are handled by an OWL-QL server powered by the KSL Java Theorem Prover (JTP).
    - **Automated semantic translation:** if inputs or outputs for service partners are unavailable, SDS automatically constructs a service chain that translates between available parameters and those of the discovered service partner.
Inference Web (IW)

Motivation: Trust

If users (humans and agents) are to use and integrate web application answers, they must trust them.

System transparency supports understanding and trust.

Even simple “lookup” systems should be able to provide information about their sources.

As question answering systems become more complex, they may incorporate multiple hybrid information sources, multiple information manipulation techniques, integration of reasoners, conflict resolution strategies, prioritization, assumptions, etc., all of which may need explanation.

Thus, systems should be able to explain their actions, sources, and beliefs.
Explainable System Structure

- Explanation
- Understanding
- Trust
- Interaction
- Presentation
- Abstraction
- Proof Markup Language
- Information Manipulation Data
- Source Provenance Data
Inference Web (IW)

Framework for explaining question answering tasks by storing, exchanging, combining, annotating, filtering, segmenting, comparing, and rendering proofs and proof fragments.

- **Registration services** for inference engines/rules/languages, proof generation services for facilitating IW proofs
- **W3C Standard OWL specification of proofs** is an interlingua for proof interchange – *Proof Markup Language*
- **Proof abstractor** for rewriting proofs into more understandable formats
- **Proof browser** for displaying IW proofs and their explanations (possibly from multiple inference engines)
- **Proof explainer** for providing interactive explanation dialogues and strategies
- **Integrated** with Stanford’s JTP reasoner, SRI’s SNARK reasoner, ISI’s Mediator, IBM’s Unstructured Information Management Architecture, SRI’s SPARK, PROLOG, …
- Supporting DARPA projects including DAML, Ultralog, PAL, and ARDA projects including NIMD, AQUAINT.


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Explainable Semantic Discovery Service

Interaction of SDS with BPEL, service partners, and Inference Web

1. BPWS4J sends invocation message together with OWL-S service restrictions to SDS
2. SDS wraps service restrictions into OWL-QL query and invokes OWL-QL Server
3. OWL-QL Server uses JTP to find service profiles in the OWL-S KB matching the query
4. OWL-QL Server returns matching profiles in answer bundles
5. SDS constructs service chain through a matching service, and generates Inference Web proof
6. SDS invokes service partners in service chain with invocation message from BPWS4J
7. Partners execute and returns to SDS
8. SDS returns output and Inference Web explanation to BPWS4J
The Loan Finder scenario

- Construct a LoanFinder BPEL process model that decomposes its work between two partner services:
  - Credit Assessor: generates credit reports for a user
  - Lender Service: evaluates reports and offers loans to qualified applicants

- Consider case where:
  - User has recently moved to California, USA from the UK
  - User wishes to borrow from a CA-based lender for tax purposes
  - UK credit-reporting agency produces UKCreditReport
  - CA-based lender requires USCreditReport as input

- BPEL engine alone cannot account for location restriction. SDS enables dynamic discovery of CA-based lender, but still have syntactic parameter discrepancy (UKCreditReport vs USCreditReport)
### SDS-IW Loan Finder Example

#### The Loan Finder scenario

- **With semantic translation**, the SDS service chain algorithm integrates the assessor and lender using a Date Translator service introduced into the OWL-S KB.
- The SDS successfully executes the service chain and returns the response to the user together with an Inference Web proof explaining the composition:
Loan Finder Example

- SDS found a service composition using credit assessor, credit translator, and lender service because it could interoperate between services and could match profiles of services with requirements.

- Inference Web can provide details of which services were used (which were not used or were not allowed), and provides transparency and audit information.

- Explanations can be provided of failed composition efforts as well as successful efforts.
  - For example, if no credit translation was available and no US credit report was available, then US lending would have failed.
Notes on Explainable SDS

By integrating the SDS with BPEL4WS and BPWS4J and Inference Web, the industrial system gained the following abilities:

- Automatic, runtime binding of service partners
- Selection between multiple service partners based on user-defined constraints
- Integration of service partners with syntactically distinct but semantically translatable service descriptions
- Transparency for explanation, debugging, reporting, audits, and accountability

The SDS Demonstrates the Value-Added of Semantic Web Services, and in particular the use of OWL-S.

Want to learn more about SDS and Inference Web?

http://www.ksl.stanford.edu/sds
http://iw.stanford.edu

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Summary: Semantic Web Status

- Markup Language Recommendations; OWL / RDF / RDFS / XML
- Rule Languages maturing: watch the W3C Rules Workshop in April. SWRL submitted to W3C
- Ontologies for Services maturing: OWL-S, SWSL, WSMO, … watch the W3C services workshop in May
- Proof and Trust emerging: PML, NSF Cybertrust programs, policy efforts,…

- Demonstration examples exist showing possibilities, e.g.,
  - Explainable SDS (value add of sem web services integrated with WS standards like BPEL4WS WSDL supporting dynamic service bindings using user prefs and semantic translation)
  - KSL Wine Agent, etc.

- Robust tools available, e.g.,
  - UML tools for the Semantic Web: Sandpiper tool suite,
  - Open source editors (protégé, swoop, … )
  - Reasoning components (Cerebra, Fact, Racer, Pellet, JTP, …)
  - Explanation (Inference Web, PML, …)

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Original from AAAI 1999 - Ontologies Panel - updated by McGuinness

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Background

AT&T Bell Labs AI Principles Dept
- Description Logics, CLASSIC, explanation, ontology environments
- Semantic Search, FindUR, Collaborative Ontology Building Env
- Apps: Configurators, PROSE/Questar, Data Mining, …

Stanford Knowledge Systems, Artificial Intelligence Lab
- Ontology Evolution Environments (Diagnostics and Merging) Chimaera
- Explanation and Trust, Inference Web
- Semantic Web Representation and Reasoning Languages, DAML-ONT, DAML+OIL, OWL,
- Rules and Services: SWRL, OWL-S, Explainable SDS, KSL Wine Agent

McGuinness Associates
- Ontology Environments: Sandpiper, VerticalNet, Cisco…
- Knowledge Acquisition and Ontology Building – VSTO, GeON, ImEp,…
- Applications: GM: Search, etc.; CISCO : meta data org, etc.;
- Boards: Network Inference, Sandpiper, Buildfolio, Tumri, Katalytik
Inference Web Application Areas

- Information extraction – IBM T. J. Watson
- Information integration – USC ISI; Rutgers University, Stanford
- Task processing – SRI International
- Theorem proving
  - First-Order Theorem Provers – University of Texas, Austin; SRI International, Stanford
  - SATisfiability Solvers – University of Trento
  - Expert Systems – University of Fortaleza
- Service composition – University of Toronto, UCSF, Stanford
- Semantic matching – University of Trento
- Problem solving – University of Fortaleza
- Trust Networks – University of Trento, UMD

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The Semantic Web means different things to different people. It is multi-dimensional:

- Distributed data access
- Inference
- Data Integration
- Logic
- Services
- Search (based on term meaning)
- Configuration
- Agents
- ...

Different users value these dimensions differently.

Theme: Machine-operational declarative specification of the meaning of terms
Semantic Web Layers

Ontology Level

- Languages (CLASSIC, DAML-ONT, DAML+OIL, OWL, …)
- Environments (FindUR, Chimaera, OntoBuilder/Server, Sandpiper Tools, …)
- Standards (NAPLPS, …, W3C’s WebOnt, W3C’s Semantic Web Best Practices, EU/US Joint Committee, OMG ODM, …)

Rules

- SWRL (previously CLASSIC Rules, explanation environment, issues, contracts, …)

Logic

- Description Logics

Proof

- PML, Inference Web Services and

Trust

- IWTrust, Policy encodings, …

http://www.w3.org/2004/Talks/0412-RDF-functions/slide4-0.html

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The Semantic Web is made up of individual statements.

The subject and predicate are Uniform Resource Identifiers (URIs) – the object can be a URI or a specially typed literal value.
Ontology Spectrum

Catalog/ID

Terms/glossary

General

Thesauri

Formal

Formal instance

Informal is-a

Frames (properties)

Is-a (properties)

Disjointness, Inverse, part-of…

Frames

Value

Restrs.

Disjointness, Inverse, part-of…

Markup such as DAML+OIL, OWL can be used to encode the spectrum

Originally from AAAI 1999 - Ontologies Panel – updated by McGuinness

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General Nature of Descriptions

- **Class**: a WINE
- **Superclass**: a LIQUID
- **Role/Property**: grape dictates color (modulo skin)
- **Restrictions**:
  - grape: chardonnay, ..., \([\geq 1]\)
  - sugar-content: dry, sweet, off-dry
  - color: red, white, rose
  - price: a PRICE
  - winery: a WINERY

- **Value Restrictions**:
  - harvest time and sugar are related

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• Extends vocabulary of XML and RDF/S
• Rich ontology representation language
• Language features chosen for efficient implementations

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**OWL Sublanguages**

- **OWL Lite** supports users primarily needing a classification hierarchy and simple constraint features. (For example, while it supports cardinality constraints, it only permits cardinality values of 0 or 1. It should be simpler to provide tool support for OWL Lite than its more expressive relatives, and provides a quick migration path for thesauri and other taxonomies.)

- **OWL DL** supports users who need maximum expressiveness while their reasoning systems maintain computational completeness (all conclusions are guaranteed to be computed) and decidability (all computations will finish in finite time). OWL DL includes all OWL language constructs, but they can be used only under certain restrictions (for example, while a class may be a subclass of many classes, a class cannot be an instance of another class). OWL DL is named for its correspondence with *description logics*.

- **OWL Full** supports users who want maximum expressiveness and the syntactic freedom of RDF with no computational guarantees. For example, in OWL Full a class can be treated simultaneously as a collection of individuals and as an individual in its own right. OWL Full allows an ontology to augment the meaning of the pre-defined (RDF or OWL) vocabulary. It is unlikely that any complete and efficient reasoner will be able to support every feature of OWL Full.
OWL Lite Features

- RDF Schema Features
  - `Class`, `rdfs:subClassOf`, `Individual`
  - `rdf:Property`, `rdfs:subPropertyOf`
  - `rdfs:domain`, `rdfs:range`

- Equality and Inequality
  - `equivalentClass`, `equivalentProperty`, `sameAs`
  - `differentFrom`
  - `AllDifferent`, `distinctMembers`

- Restricted Cardinality
  - `minCardinality`, `maxCardinality` (restricted to 0 or 1)
  - `cardinality` (restricted to 0 or 1)

- Property Characteristics
  - `inverseOf`, `TransitiveProperty`, `SymmetricProperty`
  - ` FunctionalProperty(unique)`, `InverseFunctionalProperty`
  - `allValuesFrom`, `someValuesFrom` (universal and existential local range restrictions)

- Datatypes
  - Following the decisions of RDF Core.

- Header Information
  - `imports`, `Dublin Core Metadata`, `versionInfo`
OWL Features

- Class Axioms
  - `oneOf` (enumerated classes)
  - `disjointWith`
  - `equivalentClass` applied to class expressions
  - `rdfs:subClassOf` applied to class expressions

- Boolean Combinations of Class Expressions
  - `unionOf`
  - `intersectionOf`
  - `complementOf`

- Arbitrary Cardinality
  - `minCardinality`
  - `maxCardinality`
  - `cardinality`

- Filler Information
  - `hasValue` Descriptions can include specific value information
OWL Lite and OWL

- Overview:
  
  http://www.w3.org/TR/owl-features/

- Guide:
  
  http://www.w3.org/TR/owl-guide/

- Reference:
  
  http://www.w3.org/TR/owl-ref/

- Semantics and Abstract Syntax:
  
  http://www.w3.org/TR/owl-absyn/
Selected Technical Benefits

1. Integrating Multiple Data Sources
2. Semantic Drill Down / Focused Perusal
3. Statements about Statements
4. Inference
5. Translation
6. Smart (Focused) Search
7. Smarter Search … Configuration
8. Proof
1: Integrating Multiple Data Sources

- The Semantic Web lets us merge statements from different sources.
- The RDF Graph Model allows programs to use data uniformly regardless of the source.
- Figuring out where to find such data is a motivator for Semantic Web Services.

Different line & text colors represent different data sources.

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The Semantic Web uses Uniform Resource Identifiers (URIs) to name things. These can typically be resolved to get more information about the resource. This essentially creates a web of data analogous to the web of text created by the World Wide Web. Ontologies are represented using the same structure as content. We can resolve class and property URIs to learn about the ontology.
3: Statements about Statements

- The Semantic Web allows us to make statements about statements
  - Timestamps
  - Provenance / Lineage
  - Authoritativeness / Probability / Uncertainty
  - Security classification
  - ...

- This is an unsung virtue of the Semantic Web

From CIA World Factbook

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The formal foundations of the Semantic Web allow us to infer additional (implicit) statements that are not explicitly made.

Unambiguous semantics allow question answerers to infer that objects are the same, objects are related, objects have certain restrictions, ...

SWRL allows us to make additional inferences beyond those provided by the ontology.
5: Translation

- While encouraging sharing, the Semantic Web allows multiple URIs to refer to the same thing.

- There are multiple levels of mapping:
  - Classes
  - Properties
  - Instances
  - Ontologies

- OWL supports equivalence and specialization; SWRL allows more complex mappings.
6: Smart (Focused) Search

- The Semantic Web associates 1 or more classes with each object

- We can use ontologies to enhance search by:
  - Query expansion
  - Sense disambiguation
  - Type with restrictions
  - ....
Visage Salon

Monday 10 AM - 3:30 PM
Tuesday to Friday 10 AM - 7:30 PM
Saturday 8:30 AM - 4:30 PM
Sunday 10 AM - 4 PM

226 North Avenue
Westfield, NJ 07090

Phone: (908) 233-2726

Specializing in custom hair design and color, texture waves and correction work. Also manicures, pedicures, waxing and full retail haircare system.
7: Smarter Search / Configuration

Course Type: NON-SPICY-RED-MEAT

"Pairs well with dry red varieties. Medium-bodied wines match especially well." why?

The local knowledge base particularly recommends the following:

- MOUNTADAM PINOT NOIR
- FORMAN CABERNET SAUVIGNON
- SAUCELITO CANYON ZINFANDEL
- GARY FARRELL MERLOT
- MARIETTA OLD VINES RED
- PAGE MILL WINERY CABERNET SAUVIGNON
- CHIANTI CLASSICO
- MARIETTA PETITE SYRAH
- WHITEHALL LANE CABERNET FRANC
- MARIETTA CABERNET SAUVIGNON
- MARIETTA ZINFANDEL
- KATHRYN KENNEDY LATERAL

The recommended wines can be found below, along with some comparable selections

Web Inventory Search

Alternatively, the following varieties include many suitable matches:

- PINOT NOIR
- MERLOT
KSL Wine Agent
Semantic Web Integration Example

Uses emerging web standards to enable smart web applications

Given a meal description
  • Deborah’s Specialty
Describe matching wines
  • White, Dry, Full bodied…
Retrieve some specific options from web
  • Forman Chardonnay from DLM’s cellar, ThreeSteps from wine.com,…

Info: http://www.ksl.stanford.edu/people/dlm/webont/wineAgent/

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OWL

for representing a domain ontology of foods, wines, their properties, and relationships between them

JTP theorem prover
for deriving appropriate pairings

DQL/OWL QL
for querying a knowledge base

Inference Web
for explaining and validating answers (descriptions or instances)

Web Services
for interfacing with vendors

Connections to online web agents/information services
Utilities for conducting and caching the above transactions

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Course Type: PASTA-WITH-NON-SPICY-RED-SAUCE

"Pairs well with dry red varieties. Medium-bodied wines featuring moderate flavors match especially well."

The local knowledge base particularly recommends the following:

- MARIETTA PETITE SYRAH
- SAUCELITO CANYON ZINFANDEL
- MARIETTA ZINFANDEL
- PAGE MILL WINERY CABERNET SAUVIGNON
- GARY FARRELL MERLOT
- MARIETTA CABERNET SAUVIGNON
- CHIANTI CLASSICO
- MOUNTADAM PINOT NOIR
- MARIETTA OLD VINES RED
- WHITEHALL LANE CABERNET FRANC

The recommended wines can be found below, along with some comparable selections:

Web Inventory Search

Alternatively, the following varieties include many suitable matches:

- PINOT-NOIR
- MERLOT
- RED-BORDEAUX
The logical foundations of the Semantic Web allow us to construct proofs that can be used to improve transparency, understanding, and trust.

Proof and Trust are on-going research areas for the Semantic Web: e.g., See PML and Inference Web.

“Employees of member companies can access W3C’s content”
Inference Web

Framework for *explaining* reasoning tasks by storing, exchanging, combining, annotating, filtering, segmenting, comparing, and rendering proofs and proof fragments provided by multiple distributed reasoners.

- OWL-based Proof Markup Language (PML) specification as an interlingua for proof interchange
- IWExplainer for generating and presenting interactive explanations from PML proofs providing multiple dialogues and abstraction options
- IWBrowser for displaying (distributed) PML proofs
- IWBase distributed repository of proof-related meta-data such as inference engines/rules/languages/sources
- Integrated with theorem provers, text analyzers, web services, …

http://iw.stanford.edu

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Users can explore extracted entities and relationships, create new hypothesis, ask questions, browse answers and get explanations for answers.

(this graphical interface done by Batelle supported by KSL)
Browsing Proofs

The proof associated with an answer can be browsed in multiple formats.
Selected Technical Benefits

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7. Smarter Search … Configuration
8. Proof and Trust
Selected Papers:

Selected Tutorials:

Languages, Environments, Software:
- OWL - http://www.w3.org/TR/owl-features/ , http://www.w3.org/TR/owl-guide/
- Chimaera - http://www.ksl.stanford.edu/software/chimaera/
- TAP – http://tap.stanford.edu/
- Cerebra (formerly Network Inference) – http://www.cerebra.com
- Sandpiper Software – http://www.sandsoft.com
Protégé

- Open source ontology editor from Stanford Medical Informatics
  - Large user community
- Good GUI interface for subject-matter experts
- Extra features
  - SWRL support
  - PROMPT versioning
- http://protege.stanford.edu
Commercial OWL DL tools

- **Cerebra Construct**
  - Ontology engineering and external source mapping within a familiar MS Visio framework

- **Cerebra Server**
  - Commercial-grade inference platform, providing industry-standard query, high-performance inference and management capabilities with emphasis on scalability, availability, robustness and 100% correctness. Based on initial work from University of Manchester

- **CEREBRA Repository**
  - Collaborative object repository for metadata, vocabulary, security and policy management

[http://www.cerebra.com](http://www.cerebra.com)
Medius / Sandpiper

- Visual Ontology Modeler
  - UML-based modeling tool
  - Add-in to Rational Rose
  - Produces RDF, OWL, DAML, UML, …

- Medius Knowledge Brokering Suite

- OMG Ontology Definition Metamodel (ODM)

- [http://www.sandsoft.com](http://www.sandsoft.com)
SWOOP

- Hypermedia-based open source ontology editor
  - Includes an interface to the Pellet OWL DL reasoner

Pellet

- Open source Java OWL DL reasoner
  - API supports
    - Species validation (OWL Lite/DL/Full)
    - Consistency checking
    - Classification
    - Entailment
    - Query


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SNOBASE

- Ontology management system from IBM
  - Ontology Directory
  - Query capability
  - JOBC API

Jena

- Open source API from HP Labs UK
- Most popular Java API
  - Parser
  - Serializer
- Extra features
  - Persistence (RDBMS)
  - Query (RDQL)
  - Reasoning
  - Rule Engine
Drive

- Open source C# API
  - Parser
- Works well with COM and .NET
- http://www.driverdf.org
Open source API for Python from W3C
  - Parser
  - Serializer

Extra features
  - Introduced N3 syntax alternative to RDF/XML
  - Rule language
  - Can be used with –filter mode as a sort of XSLT for Semantic Web content

http://www.w3.org/2000/10/swap/doc/cwm.html
Sesame

- Open source query engine developed by EU
- Supports several query languages
  - RQL
  - RDQL
  - SeRQL
- Supports several persistence mechanisms
  - RDBMS
  - Native
  - User-defined
- Tomcat-based server
- http://openrdf.org
Kowari

- Scalable open source persistence
  - 500 million+ statements
  - Transaction management
  - 100% Java

- Query language (ITQL)

- [http://www.kowari.org](http://www.kowari.org)
SweetRules

- Open source rule framework

- Executes SWRL and RuleML using a variety of rule engines
  - CommonRules
  - XSB Prolog
  - JESS
  - Jena 2

- Translates between various rule formats

- [http://sweetrules.projects.semwebcentral.org](http://sweetrules.projects.semwebcentral.org)
SemWebCentral

- Open source software development site dedicated to the Semantic Web
  - 79+ projects
  - 257+ developers
- Select projects by workflow or other attributes
- http://semwebcentral.org
Other Tool Resources

- Dave Beckett’s RDF Resource Guide
  - [http://www.ilrt.bris.ac.uk/discovery/rdf/resources/](http://www.ilrt.bris.ac.uk/discovery/rdf/resources/)

- Michael Denny’s Survey of Ontology Tools
More Info

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Semantic Web Layering

From: Berners-Lee XML 2000

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Open source Integrated Development Environment using Eclipse

- Oriented toward developers
  - Code generation facilities

http://owl-eclipse.projects.semwebcentral.org
Unicorn System

- Commercial ontology editor and data source mapping tool
  - Leading enterprise information integration tool
  - Supports OWL, RDBMS schemas, XML Schema, etc.

- [http://www.unicorn.com](http://www.unicorn.com)
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