

# The Evolving Semantic Web: Current Activities and Examples

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**<http://www.ksl.stanford.edu/people/dlm>**

# Semantic Web Layers



## Ontology Level

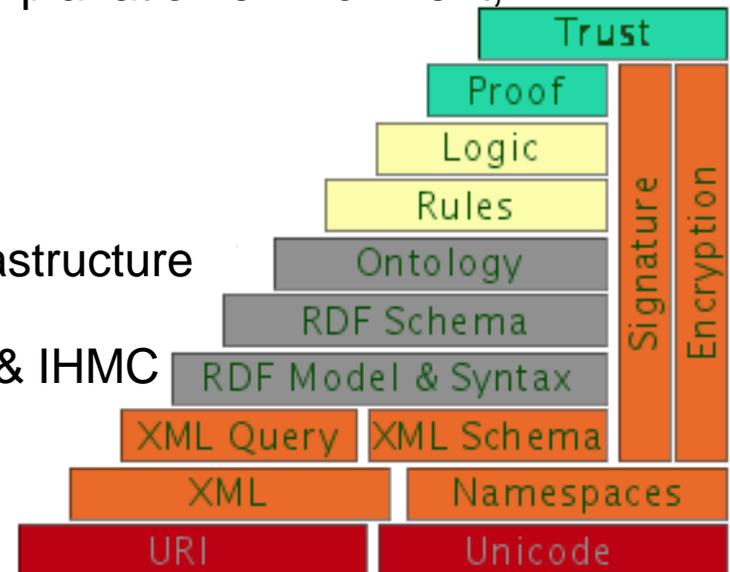
- Languages (CLASSIC, DAML-ONT, DAML+OIL, OWL, ...)
- Environments (FindUR, Chimaera, OntoBuilder/Server, Sandpiper Tools, ...)
- Services (OWL-S, SWSL, Wine Agent, Explainable SDS, ...)
- Standards (NAPLPS, ..., W3C's WebOnt, W3C's Semantic Web Best Practices, EU/US Joint Committee, OMG ODM, ...)

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

Logic : Description Logics

Proof: PML, Inference Web Services and Infrastructure

Trust: IWTrust, NSF proposals with W3C/MIT& IHMC

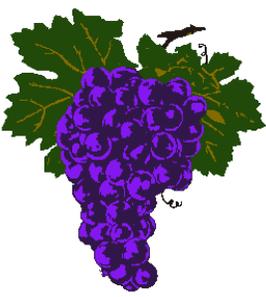


<http://www.w3.org/2004/Talks/0412-RDF-functions/slide4-0.html>

# Introduction by Example

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- **Simple B2C example (Wine Agent)**
- **Explainable Web Service Discovery and Composition (Explainable SDS)**



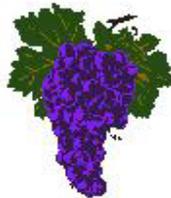
# KSL Wine Agent Semantic Web Integration

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**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:

- ◆ bland fish
- ◆ flavorful fish

### Shellfish:

- ◆ oysters
- ◆ other shellfish

## 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

## TOMATO-BASED FOOD

## DESSERT

- ◆ sweets
- ◆ nuts and cheese

## FRUIT

- ◆ sweet fruit
- ◆ unsweet fruit

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 chops](#) - [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 11:26:31 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:subClassOf rdf:resource="#MODERATE-OR-STRONG-FLAVOR-RESTRICTION"/> [ ... ]

# Processing

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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\*

<http://www.ksl.stanford.edu/projects/wine/explanation.html>

Wine Agent (version 1.0) - Microsoft Internet Explorer

Address: <http://onto.stanf.edu/~c0000/wino/index.jsp?acstring=PASTA-WITH-NON-SPICY-RED-SAUCE&wantProofs=1>

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

**"Pairs well with *dry*<sub>IW</sub> *red*<sub>IW</sub> varieties. *Medium*<sub>IW</sub>-bodied wines featuring *moderate*<sub>IW</sub> flavors match especially well."**

The local knowledge base particularly recommends the following:

- MARIETTA PETTTE SYRAH [IW](#)
- SAUCELITO CANYON ZINFANDEL [IW](#)
  - MARIETTA ZINFANDEL [IW](#)
- PAGE MILL WINERY CABERNET SAUVIGNON [IW](#)
  - GARY FARRELL MERLOT [IW](#)
- MARIETTA CABERNET SAUVIGNON [IW](#)
  - CHIANTI CLASSICO [IW](#)
  - MOUNTADAM PINOT NOIR [IW](#)
  - MARIETTA OLD VINES RED [IW](#)
- WHITEHALL LANE CABERNET FRANC [IW](#)

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

[Web Inventory Search](#)

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Alternatively, the following varieties include many suitable matches:

- [PINOT-NOIR](#)
- [MERLOT](#)
- [RED-BORDEAUX](#)

Ontology: WINES - Microsoft Internet Explorer

## Ontology: WINES

- **Name:** Wines Ontology
- **URL:** <http://ontolingua.stanford.edu/doc/chimaera/ontologies/wines/>
- **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>
- **Version:** 2000-12-01

Inference Web Registrar - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Home Search

Address <http://onto.stanford.edu:8080/iwbrowser/>



Proof Style

Current URL: <http://onto.stanford.edu:8080/iwbrowser/>

For all values of ?instand ?x: ?inst has a color ?x when new-course15 has a drink ?inst, and red-color-restriction restricts the property to have a value of ?x. Red-color-restriction restricts the property to have a value of ?x.

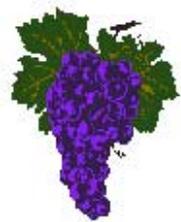
**GMP**

For all values of ?x: wine15 has a color ?x when red-color-restriction restricts the property to have a value of ?x. Red-color-restriction restricts the property to have a value of ?x.

Wine15 has a color RED.

Inference Web: [ [Home](#) | [Spec](#) | [Browser](#) | [Registrar](#) | [Registry](#) ]

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[webmaster@ksl.stanford.edu](mailto:webmaster@ksl.stanford.edu)



# 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](#)
- [CHLANTI CLASSICO at Wine.com](#)
- [CHLANTI 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

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- 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)

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- **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)

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## 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.

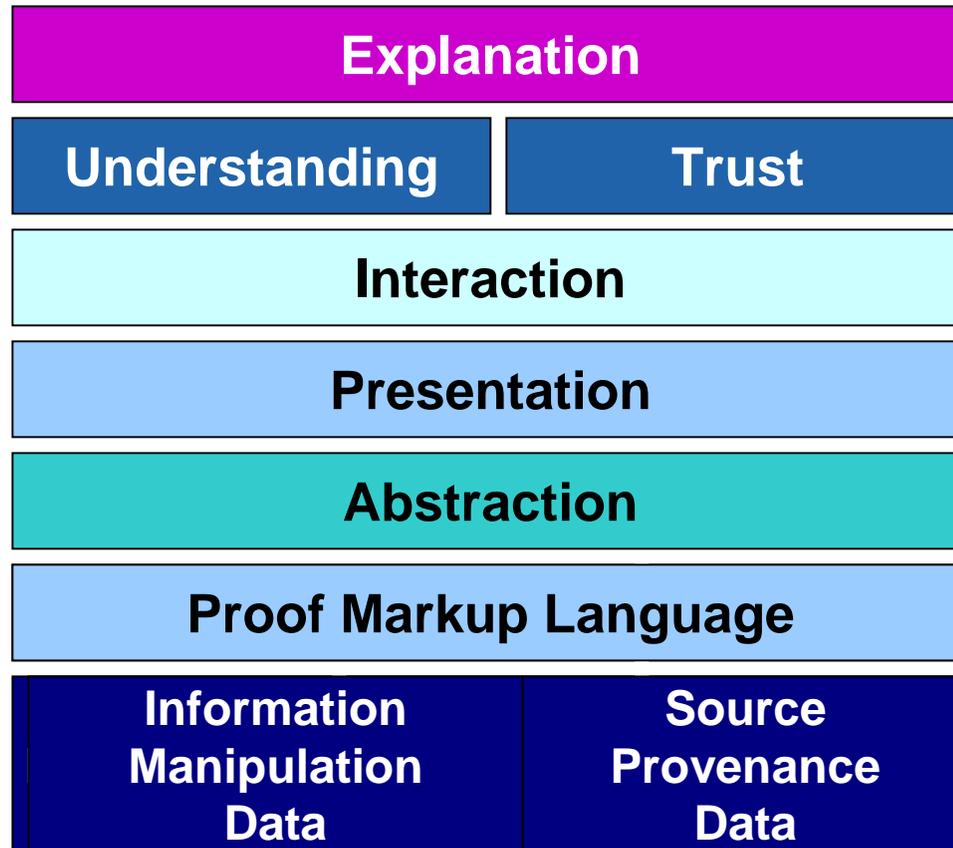
Even simple “lookup” systems should be able to provide information about their sources.

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

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# Inference Web (IW)

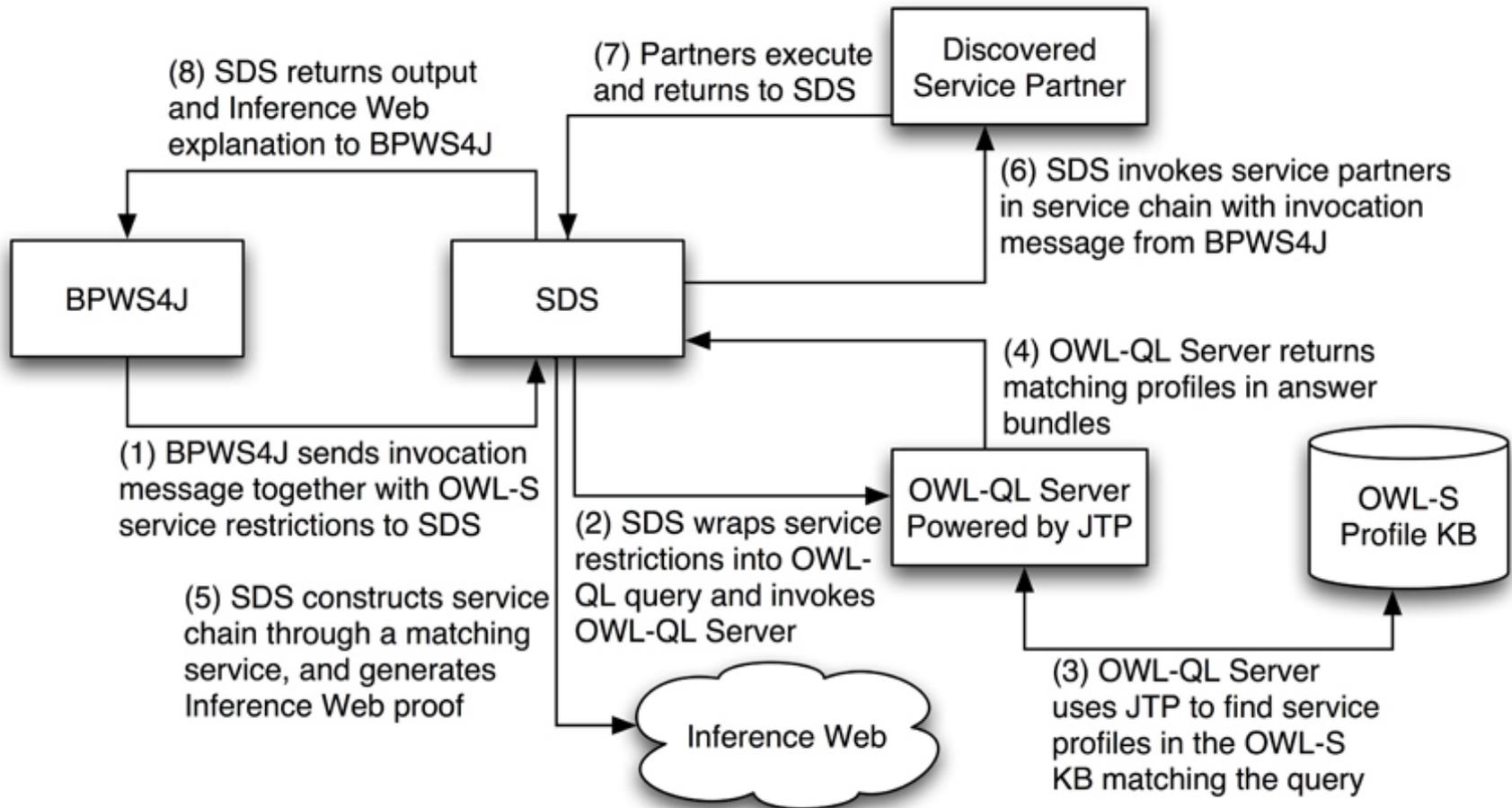
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Framework for *explaining* question answering tasks by storing, exchanging, combining, annotating, filtering, segmenting, comparing, and rendering proofs and proof fragments.

- *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 abtractor* 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.

# Explainable Semantic Discovery Service

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



# SDS-IW Loan Finder Example

## ■ The Loan Finder scenario

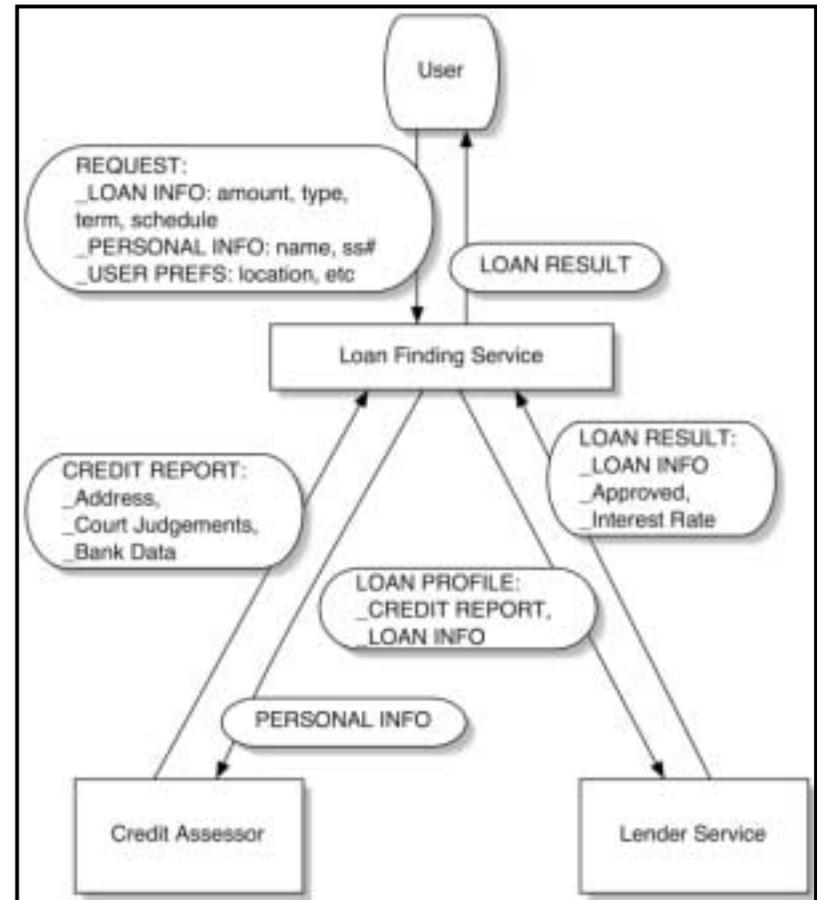
- **Construct a LoanFinder BPEL process model that decomposes its work between two partner services:**

- ◆ 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

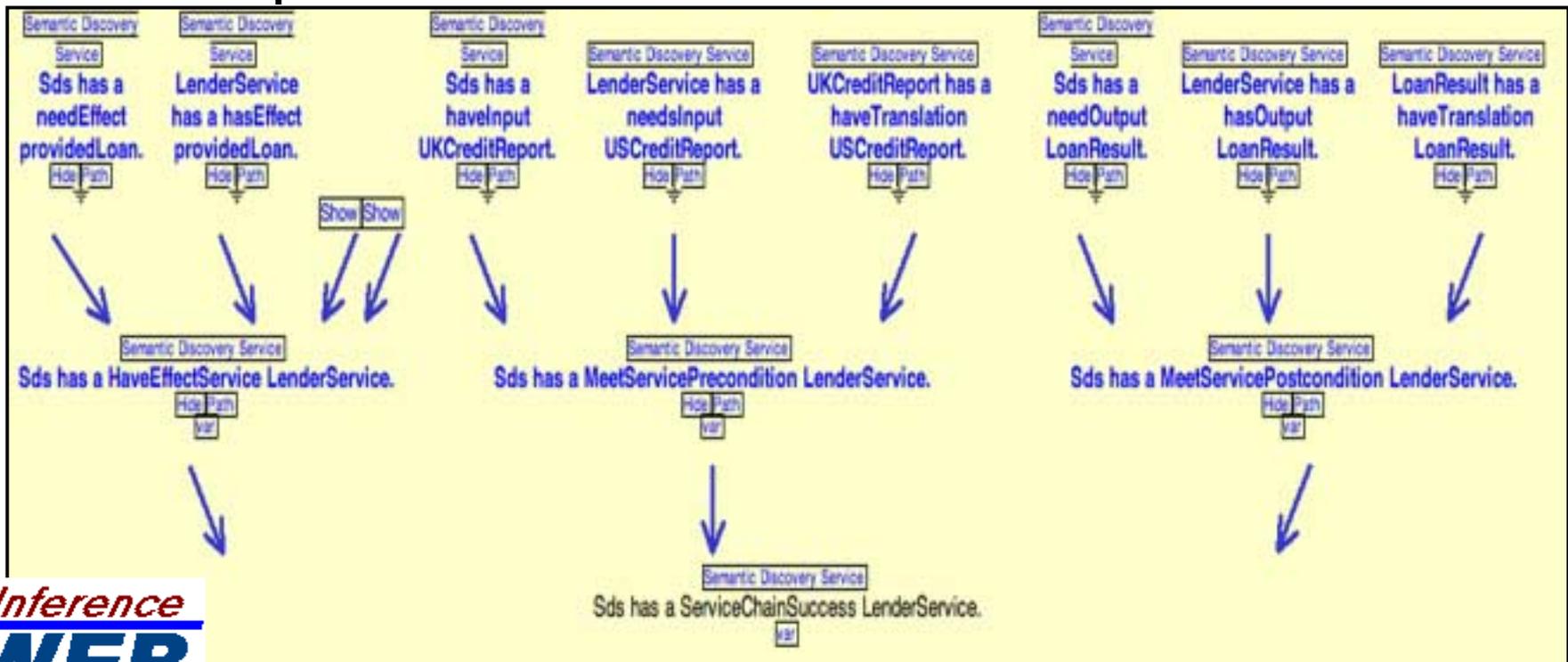
- **BPEL engine alone cannot account for location restriction. SDS enables dynamic discovery of CA-based lender, but still have syntactic parameter discrepancy (UKCreditReport vs USCreditReport)**



# 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

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- **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

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- **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>

# Summary: Semantic Web Status

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- 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, ...)



# Extras

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# Background

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## **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

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- **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**