

Intelligent

Where are all the ^ agents?

Jim Hendler

RPI

<http://www.cs.rpi.edu/~hendler>

Some personal history

- Late 1980's: dynamic planning agents
- Mid 1990's: robotics/reactive systems
- Late 1990's: DARPA
 - Head of "Agent-Based Systems"
 - Launched "DARPA Agent Markup Language"
 - Funded emerging "semantic web" area
 - Service-based middleware for agents
- March 2001: Agents on the Semantic Web
 - Proposes "Semantic Web Services" approach
- Early 2000's: Semantic Web Service Composition using AI planning
- Now: Semantic Web, Web Science (*CACM July 08*)



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What we said then...



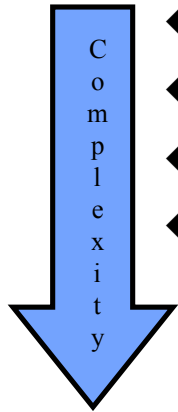
Slides from a May 2001 talk

Which grow out of an inclusive definition of agency



- An agent is a software component or system that is:

- ◆ Dynamic in its behaviors (not single I/O mapping)
- ◆ Embedded in, and “aware” of, an environment
- ◆ User enabled/steered, but “empowered” to act for user
- ◆ Able to improve its behavior over time



Autonomous

Communicative

Capable

Adaptive

Environment

Output(t+1)

Input(t)

Real-time
processing

Tuning and/or
adaptation

User/system goal assessment

(Virtual) Machine Base

[Http://helix.nature.com/webmatters](http://helix.nature.com/webmatters)

- **DARPA will lead the way with the development of Agent markup Language (DAML)**
 - ◆ A “semantic” language that ties the information on a page to machine readable semantics (ontology)
 - Currently being fielded at University level
 - ◆ SHOE (Maryland), Ontobroker(Karlsruhe), ...
 - ◆ Largely grows from past DARPA programs (I3, ARPI)
 - But not transitioning
 - ◆ W3C focused on short-term gain:HTML/XML

```
<Title> Beyond XML
  <subtitle> agent semantics </subtitle>  </title>
<USE-ONTOLOGY ID="PPT-ontology" VERSION="1.0"
PREFIX="PP" URL= "http://iwp.darpa.mil/ppt..html">
<CATEGORY NAME="pp.presentation"
FOR="http://iwp.darpa.mil/jhender/agents.html">
  <RELATION-VALUE POS1 = "Agents" POS2 = "/jhender">
```

```
<ONTOLOGY ID="powerpoint-ontology" VERSION="1.0"
DESCRIPTION="formal model for powerpoint presentations">
<DEF-CATEGORY NAME="Title" ISA="Pres-Feature" >
<DEF-CATEGORY NAME="Subtitle" ISA="Pres-Feature" >
<DEF-RELATION NAME="title-of"
  SHORT="was written by">
  <DEF-ARG POS=1 TYPE="presentation">
  <DEF-ARG POS=2 TYPE="presenter" >
```

Research and Industry Working Together



| | | |
|-------------|-----------------------------|---------------|
| DAML | DAML-Logic | DAML-Ontology |
| | RDF-Schema-extensions | |
| RDF | Existing W3C Recommendation | |
| XML | Existing W3C Recommendation | |

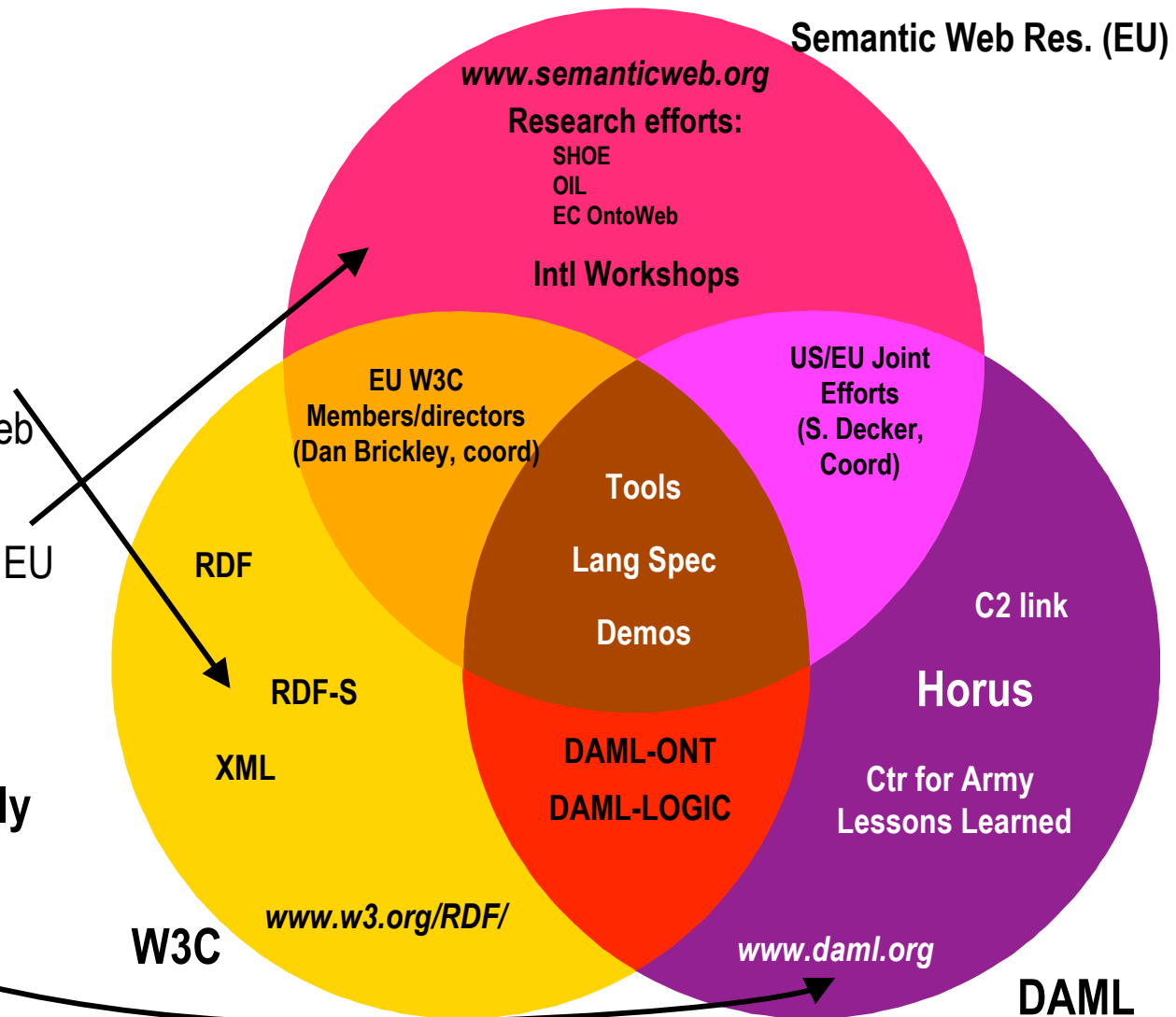
- DAML is being built on existing web “standards”, by many of the same people who developed them
 - PI Team includes MIT researchers who also head up World Wide Web Consortium:
 - PI/Co-PI: Tim Berners-Lee, Ralph Swick, Dan Connolly

DAML Technical Approach



DARPA:

- Funds a new generation of www technology
 - ♦ Works closely with W3C to create a web standard
 - ♦ Works closely with EU on international acceptance
- Brings DoD users (J2,J3,J6) in as early adopters



DAML Examples

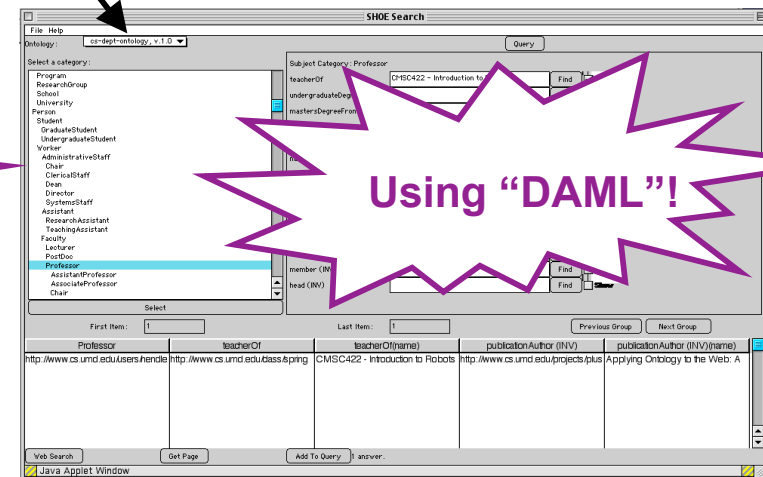


- “Transparent” Markup
- Content-Based Search
- Service advertising



```
xterm
| ?- travel('Bob Chen','09/02/00','09/06/00','San Francisco','Monterey','DAML').
Contacting Web Service Broker:
Request Driving Time [San Francisco] - [Monterey]
Result 2
Contacting Web Service Broker:
Request Car Info in [San Francisco]
Result
<B>HERTZ<B>Shuttle to Car Coun...
<B>ACE<B>Off Airport, Shuttle Pr...
<B>NATIONAL<B>Shuttle to Car Coun...
<B>FOX<B>Off Airport, Shuttle Pr...
<B>PAYLESS<B>Off Airport, Shuttle...
<B>ALL INTL<B>Off Airport, Shuttle...
<B>HOLIDAY<B>Off Airport, Shuttle...
<B>ABLE RENT<B>Off Airport, Shuttle...
Select
HERTZ (San Francisco Airport), Local Shuttle to Car Counter, Economy C
ar Automatic with Air Conditioning, Unlimited Mileage
Contacting Web Service Broker:
Request Hotel Info in [Monterey]
Result
<B>Travelodge<B> Monterey, CA<B>65 Rooms / 2 Floors<B>No...
<B>Econolodges<B>MONTEREY, CA<B>47 Rooms / 2 Floors<B>1...
<B>Lexington Services<B> Monterey, CA<B>52 Rooms<B>Not A...
<B>Ramada Inns<B> Monterey, CA<B>47 Rooms<B>Not Availabl...
<B>Best Western Intl<B> Monterey, CA<B>43 Rooms / 3 Floo...
<B>Motel 6<B> Monterey, CA<B>52 Rooms / 2 Floors<B>Not A...
<B>Villager Lodge<B> Monterey, CA<B>55 Rooms / 2 Floors<B>...
<B>Best Western Intl<B> Monterey, CA<B>34 Rooms / 2 Flo...
```

Reading “DAML”!



Using “DAML”!

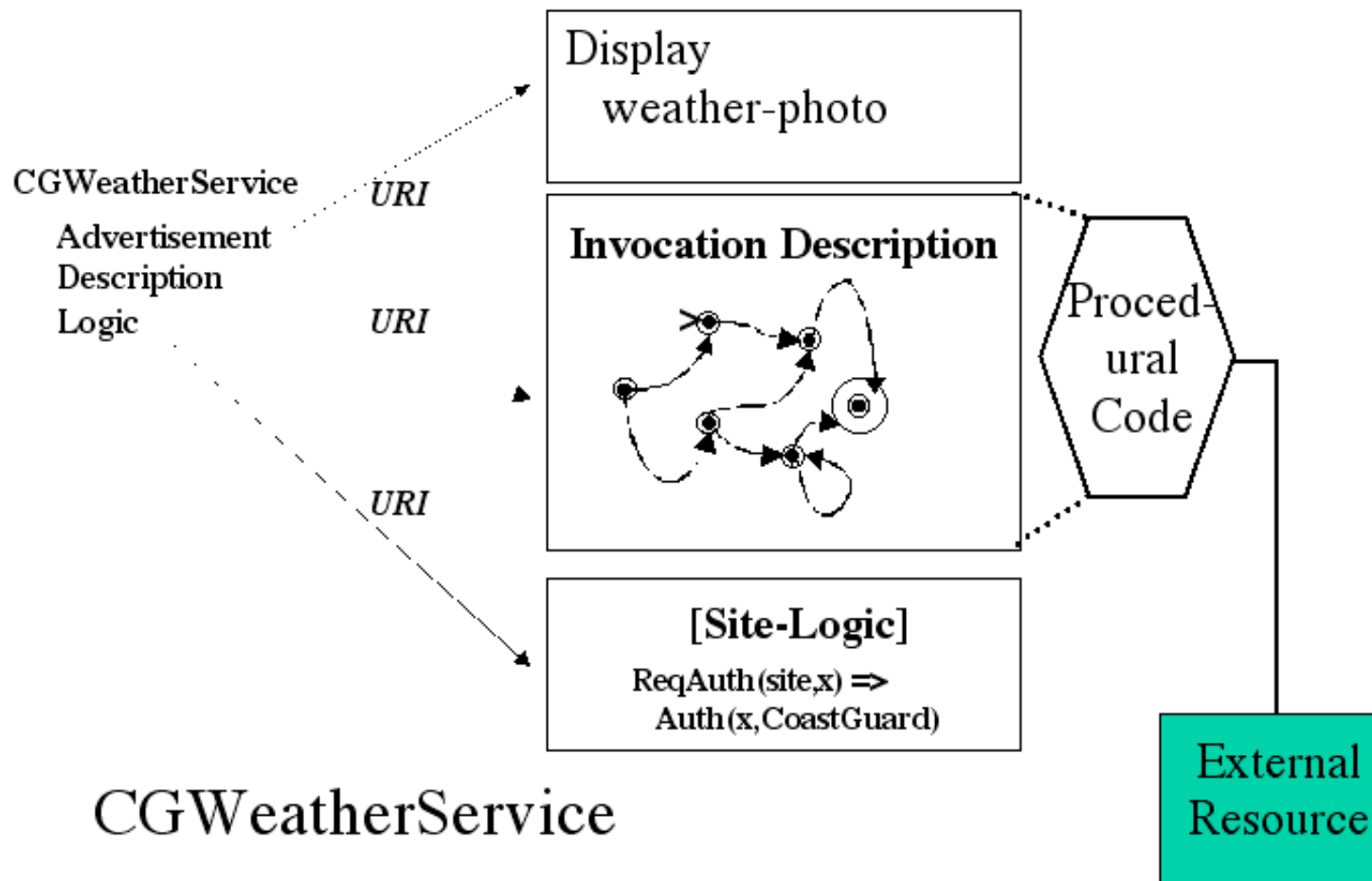
Web “travel” agents



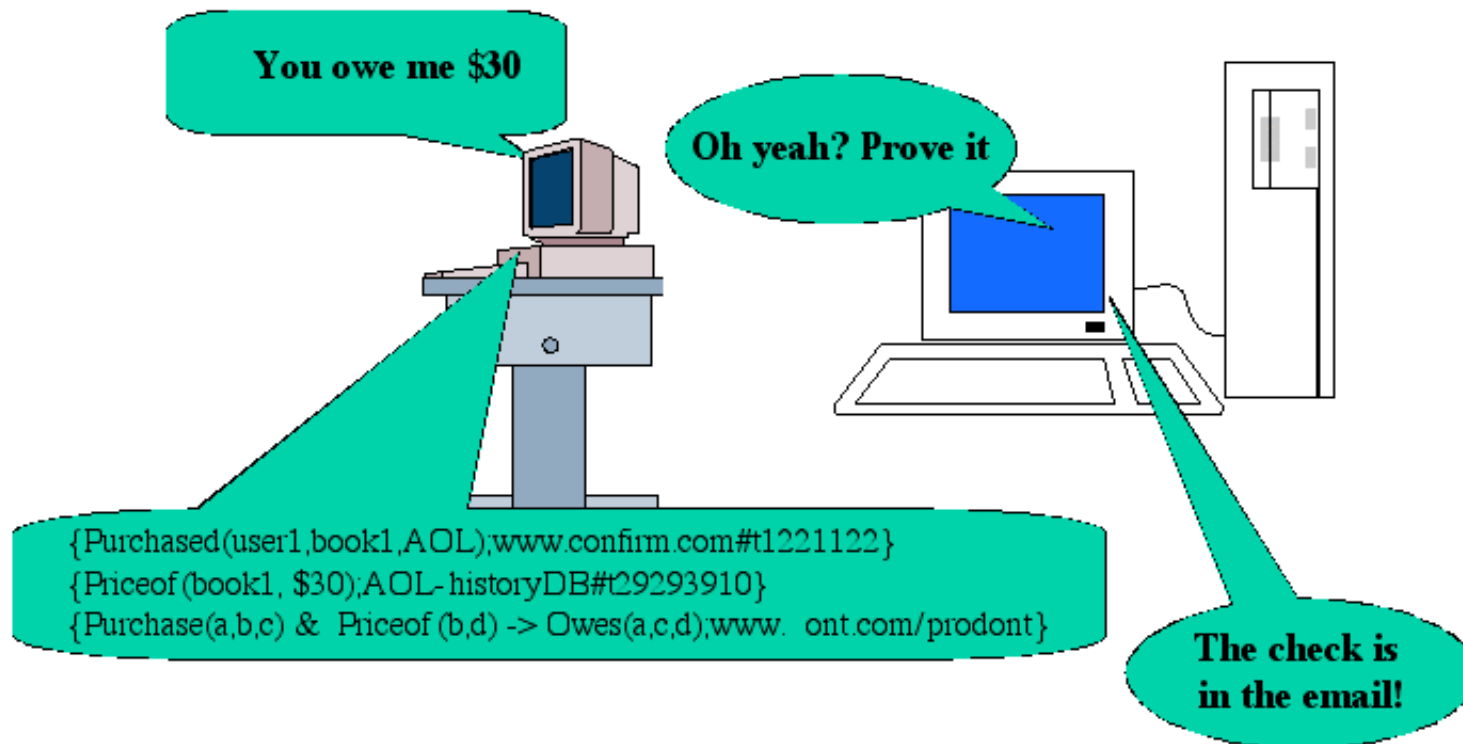
Query processed:

- ◆ A satellite image taken yesterday at 10 AM is available on the web at [http://...](#)
- ◆ A new satellite image, to be taken today at 10AM, will be available for \$100 — [click here](#) to authorize transfer of funds and obtain image (you will need a valid credit card number from one of the following providers: ...)
- ◆ In an emergency situation, a Coast Guard observer plane can be sent to any location within the area you indicate. Service Note: You will be responsible for cost of flight if the situation does not result in emergency pickup. [Click Here for more information.](#)
- ◆ A high altitude observer can be sent to your location in 13 hours. [Click here](#) to initiate procedure. (You will need to provide US military authorization, A valid military unit code, and the name of commanding officer)
- ◆ A service entitled “commercial service for providing satellite images” is advertised as becoming available in 2004. See [http://...](#) for more information

Service Descriptions



Web Logics



Which brings us to today...

- The Semantic Web is real
- The knowledge is out there
- The service infrastructure exists
- Plenty of software tools ranging from .net to WSDL to SAWSDL to OWL

So where are all the agents?



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Semantic Web ca. 2008

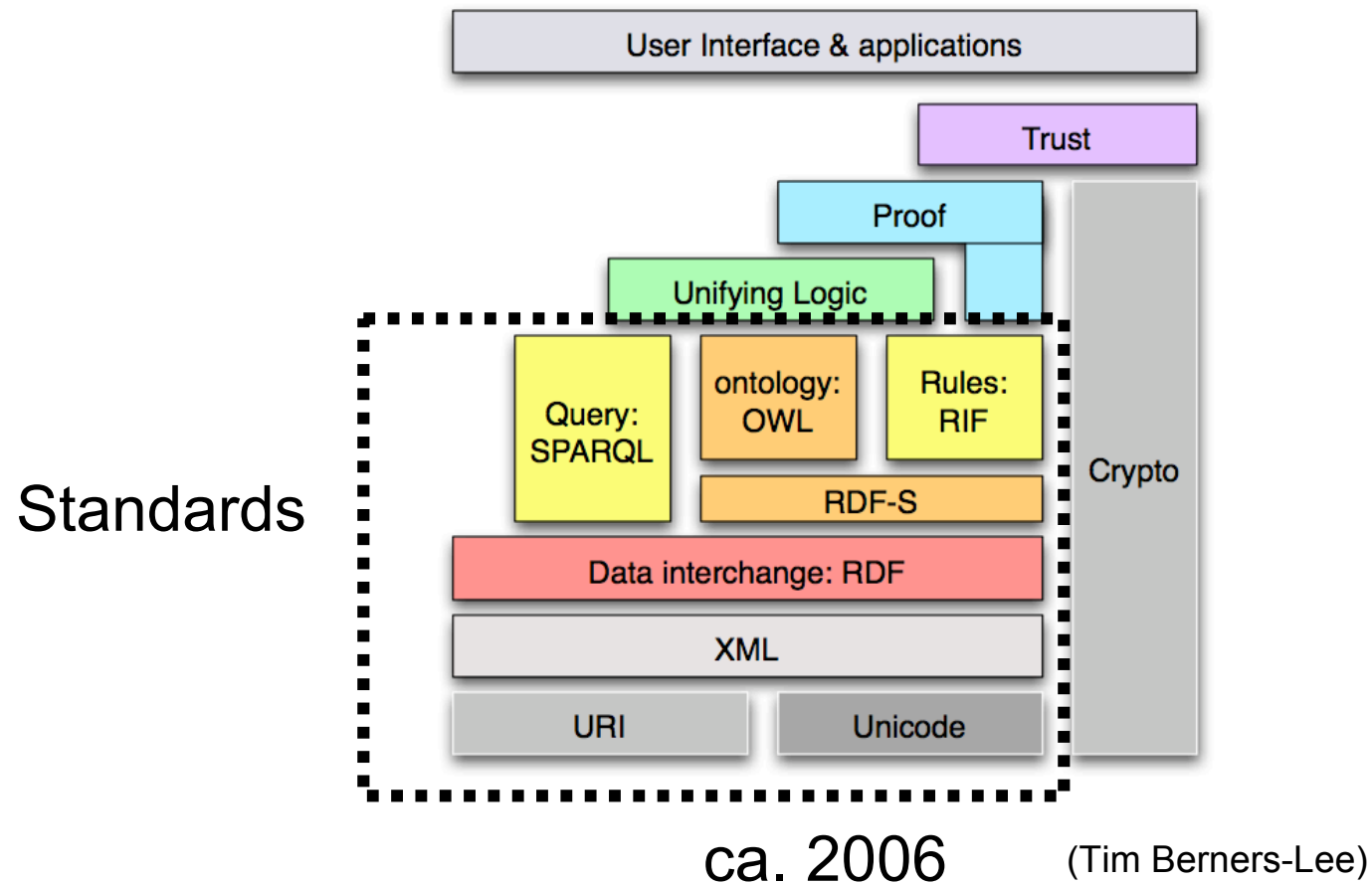
- **Semantic Web** companies starting & growing
 - Siderean, SandPiper, SiberLogic, Ontology Works, Intellidimension, Intellisophic, TopQuadrant, Data Grid, Mondeca, ontoPrise...
 - Web 3.0 new buzzword: Garlik, Metaweb, RadarNetworks, Joost, Talis, ...
- Bigger players buying in
 - Adobe, Cisco, HP, IBM, Microsoft, Nokia, Oracle, Sun, Vodaphone, Yahoo!, Reuters, ...
 - Gartner identifies Corporate Semantic Web as one of three "High impact" Web technologies
 - Tool market forming: AllegroGraph, Altova, TopBraid, ...
 - Underlying technology for some large web sites (Yahoo Sites, eHarmony,)
 - Microsoft buys Powerset (\$100,000,000) - July 2008
- Government projects in and across agencies
 - US, UK, EU, Japan, Korea, China, India...
- Several "verticals" heavily using Semantic Web technologies
 - Health Care and Life Sciences
 - Interest Group at W3C
 - Financial services
 - Human Resources
 - Sciences other than Life Science
 - Virtual observatory, Geo ontology, ...
- Many open source tools available
 - Kowari, RDFLib, Jena, Sesame, Protégé, SWOOP, Pellet, Onto(xxx), Wilbur, ...



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Semantic Web "Stack"



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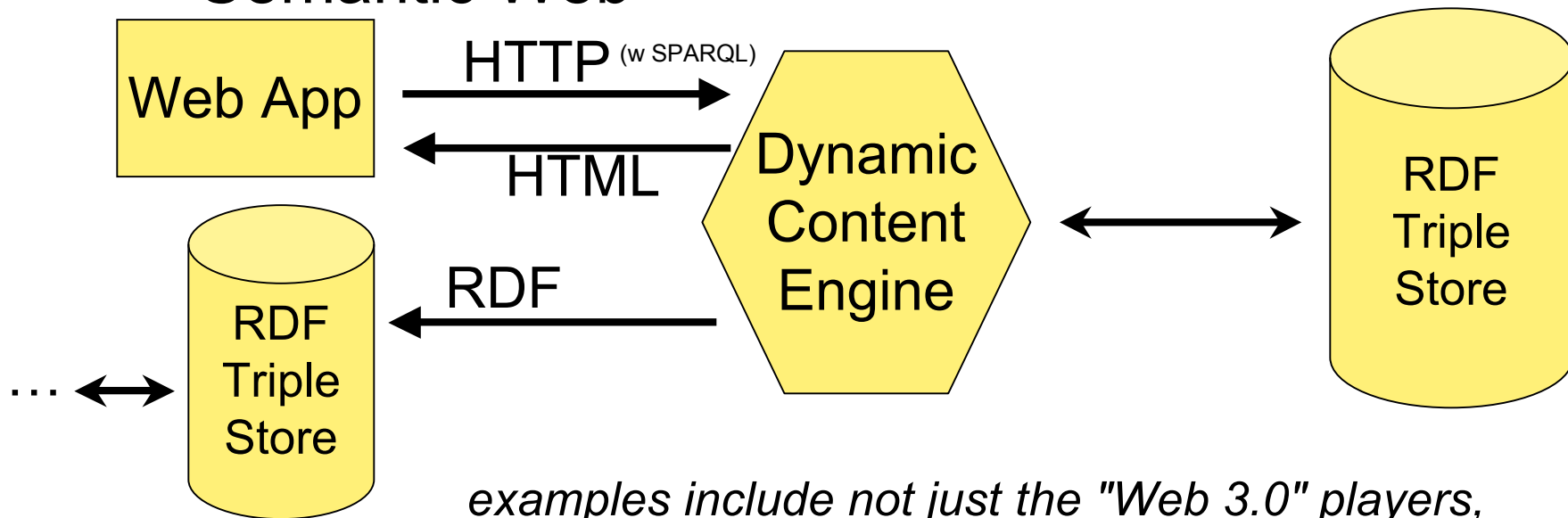


Agents opportunity: "Web 3.0"

- The "Data Web" approach finds its use cases in Web Applications (at Web scales)
 - A lot of data, a little semantics
 - Finding anything in the mess can be a win!
- Example
 - Declare simple inferable relationships and apply, at scale, to large, heterogeneous data collections
 - eg. Use InverseFunctional triangulation to find the entities that can be inferred to be the same
 - These are "heuristics" not every answer must be right (qua Google)
 - But remember *time = money!*

Web 3.0 is happening

- ~2006: Web app developers discover the Semantic Web



examples include not just the "Web 3.0" players, but also sites from Dow Jones and Reuters to eHarmony and Yahoo!




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Agent-like needs

- Twine recommends some people I may want to connect to
 - What is correctness in this case?
 - If I find some folks I like this way, I use twine more. Surprises can be fun.
 - I'm only seeing a few of a very large set (think Google) so "first" is more important than "there somewhere"
 - Argues for something other than completeness or minimal cost
 - "interesting" is important


Recommended Members




Mills Davis
Washington DC USA
83 Twines | 182 Items
Connection Pending




Chris Jones
All ready for '08
Mill Valley
58 Twines | 65 Items
[Connect](#)



John Clarke Mills
doing things and stuff
San Francisco, CA
28 Twines | 34 Items
[Connect](#)



Steve O'Donoghue
Twining my interests
San Francisco
27 Twines | 181 Items
[Connect](#)




tricia
arbiter of style
san francisco, ca
52 Twines | 952 Items
[Connect](#)

twine

Home My Items My Twines My Connections Explore Start a Twine Search Twine

Member Profile



tricia
arbiter of style
san francisco, ca
Member since: Oct 3, 2007
<http://www.bitsandbobbins.com/journal>
<http://www.wardroberemix.com>

Mutual Twines

2 Twines


- Web 3.0 - Semantic Web
897 Items | 2218 Members
- Twine News and ...
47 Items | 3971 Members

tricia's Twines


52 Twines

- Web 3.0 - Semantic Web
897 Items | 2218 Members
- Twine News and ...
47 Items | 3971 Members


5 connections




Candice Nobles
happy to be here!
San Francisco, CA
61 Twines | 59 Items
Disconnected




James Todd
living large
05008
72 Twines | 267 Items
Disconnected



Nova Spivack
Learning from Twine,
San Francisco, CA 94107
284 Twines | 2338 Items
Disconnected



Hravn Thorisson
A 1400g Crimson Jelly
Reykjavik, Iceland
233 Twines | 851 Items
Disconnected

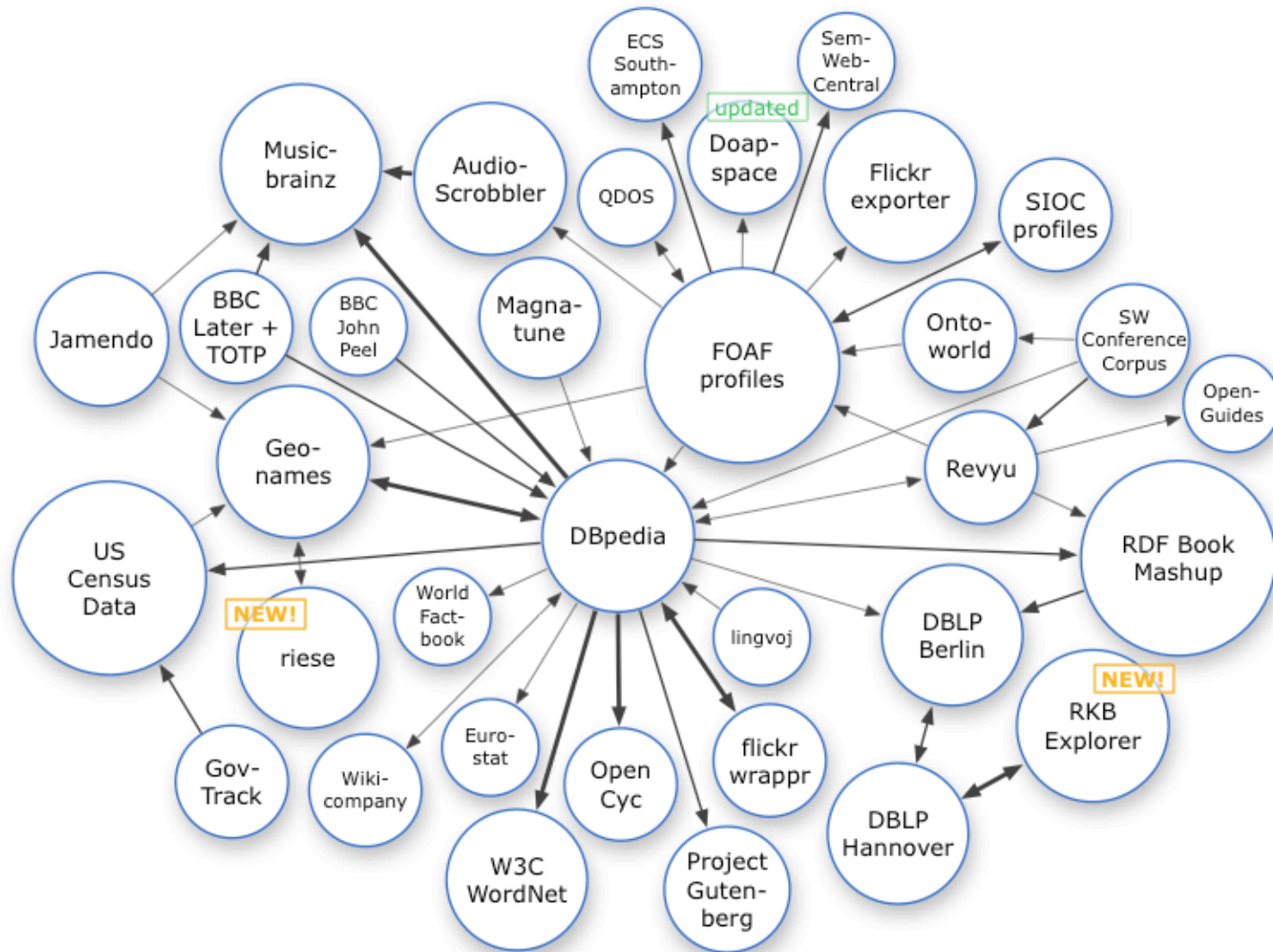


Dan Perry
www.danperry.com
34 Twines | 106 Items
Disconnected



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The linked open data cloud now has billions of assertions, and is growing rapidly

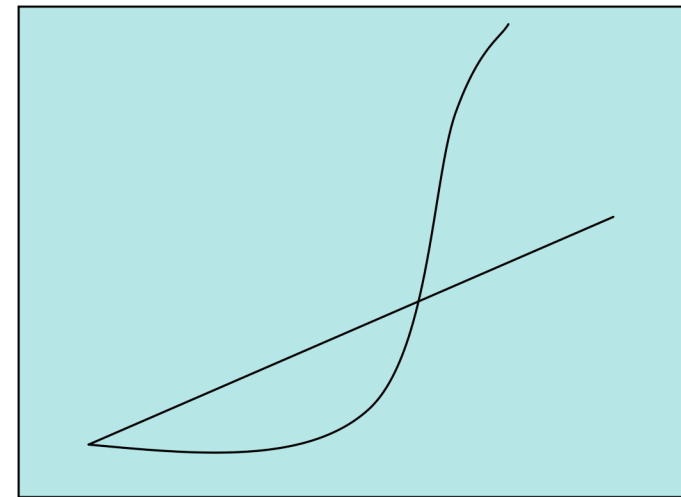


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Linking is power

- Today we can find thousands of ontologies
 - Available on the Web
 - Linked to Web resources
 - Linked to data resources
 - Linked to each other
 - Linked to Web 2.0-like annotations
- And billions of annotated (semi-Knowledge engineered) objects
 - Available on the Web
 - Linked to Web resources
 - Linked to data resources
 - Linked to each other
 - Linked to the ontologies
- Many Large (and curated) "Vocabularies" for Grounding Applications
 - Natl Library of Agriculture (SKOS)
 - NCI Ontology (OWL)
 - Getty Catalog (OWL, licensed), UMLS (RDFS, licensed),
 - GeoNames (RDF), PlaceNames (OWL, proprietary)
 - ...



Metcalfe's Law



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The Wine Agent/Ontology

- Original view: Consensus knowledge of wine and food
 - Lots of debate in its creation
 - Everyone had to agree
 - Eventually completed with "correct" wine recommendations
 - You disagree, tough! You're wrong.

Wine Ontology Take II



TW Wine Agent

[Overview](#)
[Acknowledgements](#)

To view recommendations for a given type of food, click the desired food in the menu below.

- [Expand](#) * [Meat \(1 / 13 below\)](#)
- [Expand](#) * [Fowl \(0 / 6 below\)](#)
- [Expand](#) * [OtherTomatoBasedFood \(1 / 1 below\)](#)
- [Collapse](#) * [Seafood \(2 / 24 below\)](#)
 - * [Shrimp \(1 / 0 below\)](#)
 - * [Shellfish \(1 / 8 below\)](#)
 - * [Non Oyster Shellfish \(1 / 5 below\)](#)
 - * [Crab \(2 / 0 below\)](#)
 - * [Mussels \(1 / 0 below\)](#)
 - * [Lobster \(1 / 0 below\)](#)
 - * [Clams \(1 / 0 below\)](#)
 - * [Oyster Shellfish \(1 / 1 below\)](#)
 - * [Oysters \(1 / 0 below\)](#)
 - * [Fish \(3 / 11 below\)](#)
 - * [Non Bland Fish \(2 / 4 below\)](#)
 - * [Tuna \(1 / 0 below\)](#)
 - * [Swordfish \(3 / 0 below\)](#)
 - * [Bland Fish \(2 / 3 below\)](#)
 - * [Flounder \(1 / 0 below\)](#)
 - * [Scrod \(1 / 0 below\)](#)
 - * [Halibut \(1 / 0 below\)](#)
- [Expand](#) * [Fruit \(1 / 5 below\)](#)
- [Expand](#) * [Dessert \(1 / 8 below\)](#)
- [Expand](#) * [Pasta \(3 / 9 below\)](#)



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TW Wine Agent

[Overview](#)
[Acknowledgements](#)

Why MountEdenVineyardEdnaValleyChardonnay was selected for Fish

Wine Properties

NAME: MountEdenVineyardEdnaValleyChardonnay
COLOR: White
BODY: Medium
FLAVOR: Moderate
SUGAR: Dry

List of recs being considered

Supporting Recs

TOTAL IN SUPPORT: 9

| ID | COLOR | BODY | FLAVOR | SUGAR |
|--|-------|---------------|-------------------|-------|
| MountEdenVineyardEdnaValleyChardonnay | White | Medium | Moderate | Dry |
| Bland-2Dfish | White | Medium U Full | Moderate U Strong | |
| RecDLM Swordfish | White | Medium | Moderate | Dry |
| RecDLM Tuna | White | Medium | Moderate | Dry |
| RecSwordfish | White | Medium | | |
| RecNonBlandFish | White | | Moderate | |
| RecDLM NonBlandFish | White | Medium | Moderate | Dry |
| RecFish | White | | Moderate | Dry |
| RecDLM Fish | | Medium | | Dry |
| RecSeafood | White | | | |

Opposing Recs

TOTAL IN CONFLICT: 6

| ID | COLOR | BODY | FLAVOR | SUGAR |
|--|-------|---------|------------|---------|
| MountEdenVineyardEdnaValleyChardonnay | White | Medium | Moderate | Dry |
| RecDLM_Scrod | White | Medium | Delicate ✖ | Dry |
| Melville_Estate_Chardonnay_2006 | White | Light ✖ | Strong ✖ | Sweet ✖ |
| RecDLM_Halibut | White | Medium | Delicate ✖ | Dry |
| Rec-2Dhendler | Red ✖ | Light ✖ | | Dry |
| RecDLM_Flounder | White | Medium | Delicate ✖ | Dry |
| RecDLM_BlandFish | White | Medium | Delicate ✖ | Dry |



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TW Wine Agent

[Overview](#)
[Acknowledgements](#)

Why LongridgeMerlot was selected for Swordfish

Wine Properties

NAME: LongridgeMerlot
COLOR: Red
BODY: Light
FLAVOR: Moderate
SUGAR: Dry

List of recs being considered

Supporting Recs

TOTAL IN SUPPORT: 1

| ID | COLOR | BODY | FLAVOR | SUGAR |
|------------------------|-------|-------|----------|-------|
| LongridgeMerlot | Red | Light | Moderate | Dry |
| Rec-2Dhendler | Red | Light | | Dry |

Opposing Recs

TOTAL IN CONFLICT: 6

| ID | COLOR | BODY | FLAVOR | SUGAR |
|---------------------------------|---------|----------|----------|---------|
| LongridgeMerlot | Red | Light | Moderate | Dry |
| RecSwordfish | White ✗ | Medium ✗ | | |
| RecNonBlandFish | White ✗ | | Moderate | |
| Melville_Estate_Chardonnay_2006 | White ✗ | Light | Strong ✗ | Sweet ✗ |
| RecFish | White ✗ | | Moderate | Dry |
| RecDLM_Swordfish | White ✗ | Medium ✗ | Moderate | Dry |
| RecSeafood | White ✗ | | | |

[back](#)



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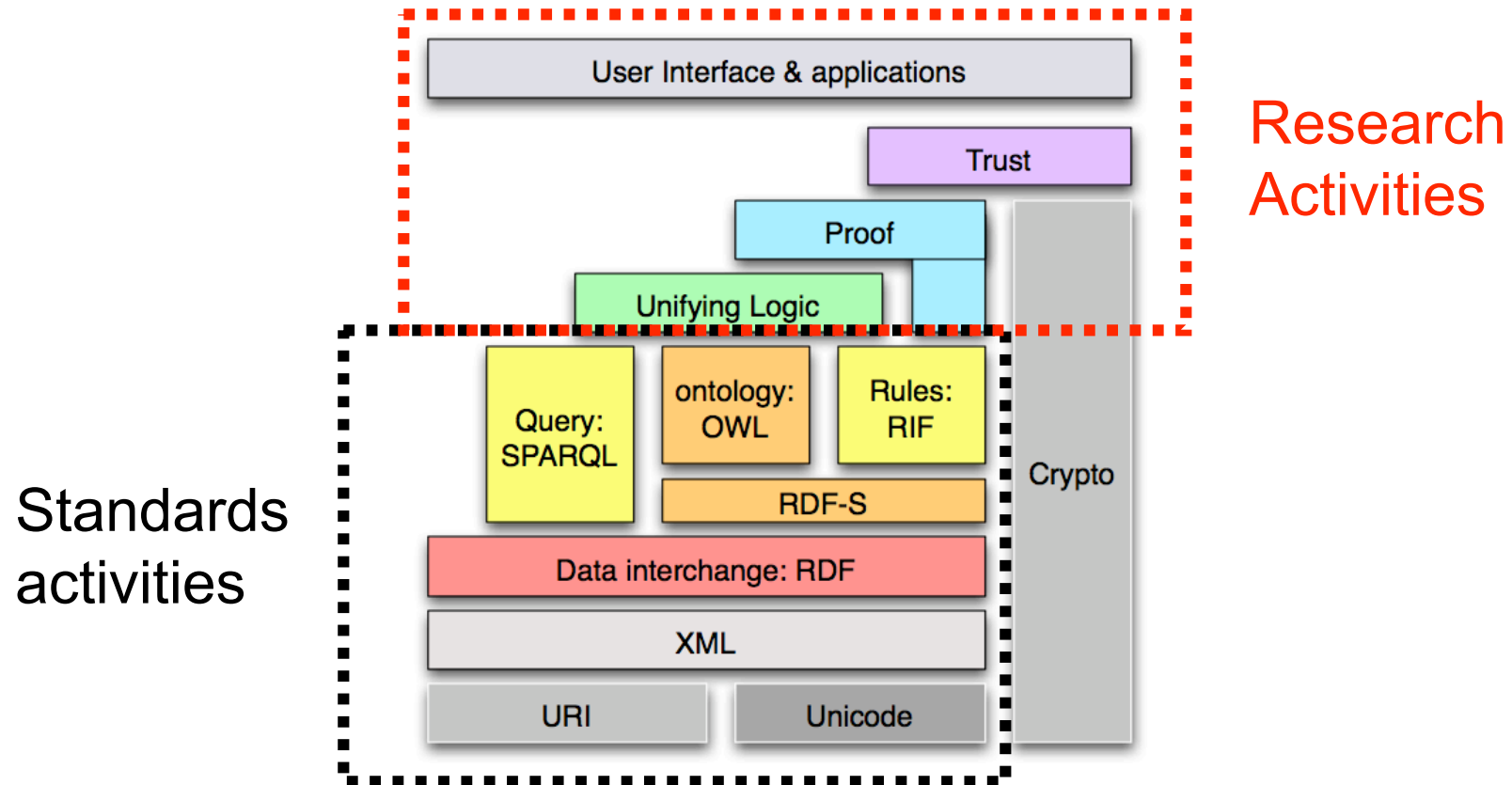


Wine Agent, next steps

- Android (Google open source phone OS)
 - Phone knows your location (and thus what restaurant you are in)
 - And often the menu
 - And often the wine list
 - Browser knows your friends (and thus their wine preferences)
 - So we can say "I'm having the sole, Jane is having the beef, and Fred the Salmon" and express some price ranges
 - And it can say "I recommend <wine>"
- Sounds like an intelligent agent in the old sense, doesn't it...



Semantic Web "Stack"



ca. 2006

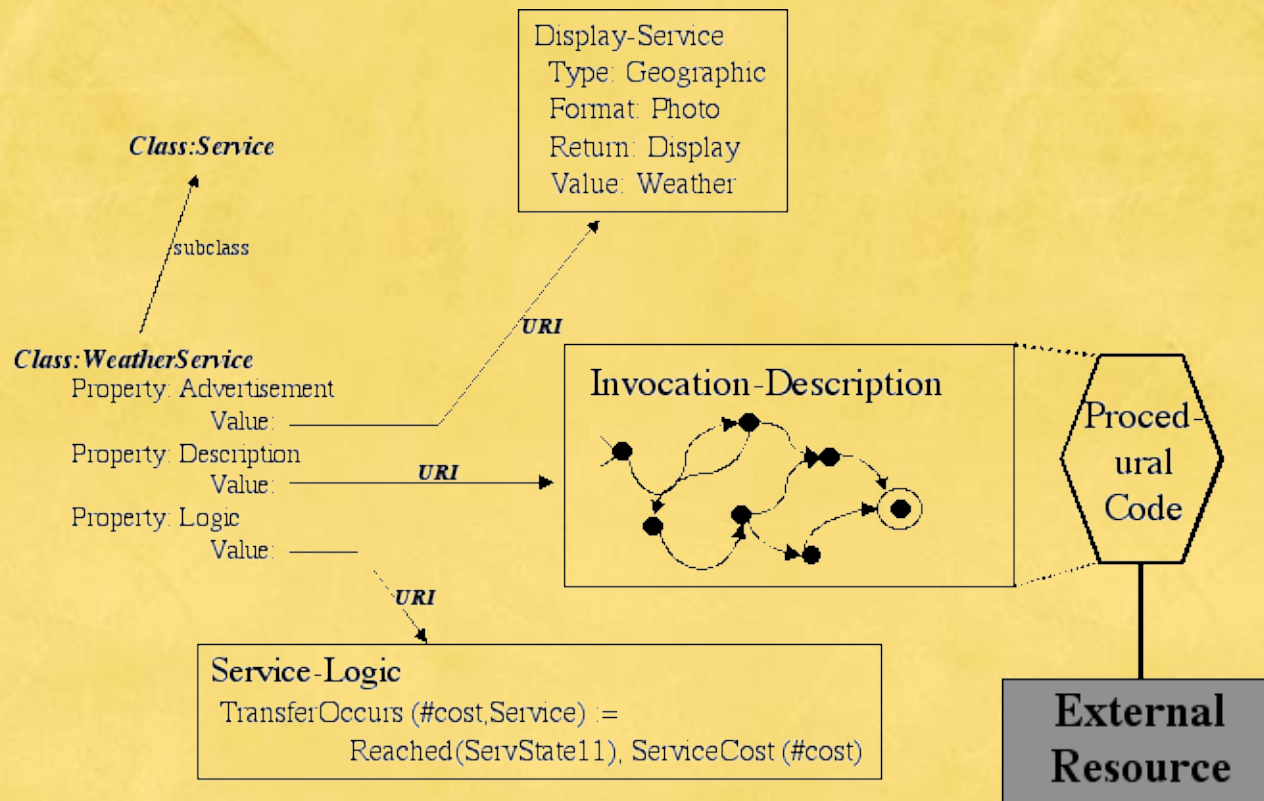
(Tim Berners-Lee)



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Web Agents need Service Descriptions



Hendler, 2001



Renaissance



Semantic Web Service Description

```
- <daml:Class rdf:ID="CreateAcct">
  <rdfs:subClassOf
    rdf:resource="http://www.daml.org/services/daml-
s/2001/10/Process.daml#AtomicProcess" />
- <rdfs:subClassOf>
  - <daml:Restriction daml:cardinality="1">
    <daml:onProperty rdf:resource="#createAcctInfo" />
    </daml:Restriction>
  </rdfs:subClassOf>
- <rdfs:subClassOf>
  - <daml:Restriction daml:cardinality="1">
    <daml:onProperty rdf:resource="#createAcctOutput" />
    </daml:Restriction>
  </rdfs:subClassOf>
</daml:Class>
- <rdf:Property rdf:ID="createAcctInfo">
  <rdfs:subPropertyOf
    rdf:resource="http://www.daml.org/services/daml-
s/2001/10/Process.daml#input" />
  <rdfs:domain rdf:resource="#CreateAcct" />
  <rdfs:range rdf:resource="#AcctInfo" />
</rdf:Property>
- <rdf:Property rdf:ID="createAcctOutput">
  <rdfs:subPropertyOf
    rdf:resource="http://www.daml.org/services/daml-
s/2001/10/Process.daml#output" />
  <rdfs:domain rdf:resource="#CreateAcct" />
  <rdfs:range rdf:resource="#CreateAcctOutputType" />
</rdf:Property>
```



Grounding WSDL

input xsd:complex="oncogene"

```
<?xml version='1.0'?>
<types>
  <xsd:schema xmlns="http://www.w3.org/2001/XMLSchema"
    targetNamespace="urn:GoogleSearch">
    <xsd:complexType name="GoogleSearchRequest">
      <xsd:all>
        <xsd:element name="documentFiltering" type="xsd:boolean"/>
        <xsd:element name="searchComments" type="xsd:string"/>
        <xsd:element name="estimatedTotalResultsCount" type="xsd:int"/>
        <xsd:element name="estimatedTotalResultsCount" type="xsd:boolean"/>
        <xsd:element name="resultElements" type="typens:ResultElementAr">
        <xsd:element name="searchQuery" type="xsd:string"/>
        <xsd:element name="startIndex" type="xsd:int"/>
        <xsd:element name="endIndex" type="xsd:int"/>
        <xsd:element name="searchTips" type="xsd:string"/>
        <xsd:element name="directoryCategories" type="typens:DirectoryCa">
        <xsd:element name="searchTime" type="xsd:double"/>
      </xsd:all>
    </xsd:complexType>
  </types>
  <message name="doGoogleSearch">
    <part name="key" type="xsd:string"/>
    <part name="q" type="xsd:string"/>
    <part name="start" type="xsd:int"/>
    <part name="maxResults" type="xsd:int"/>
    <part name="filter" type="xsd:boolean"/>
    <part name="restrict" type="xsd:string"/>
    <part name="safeSearch" type="xsd:boolean"/>
    <part name="lr" type="xsd:string"/>
    <part name="ie" type="xsd:string"/>
    <part name="oe" type="xsd:string"/>
  </message>
  <message name="doGoogleSearchResponse">
    <part name="return" type="typens:GoogleSearchResult"/>
  </message>
  <operation name="doGoogleSearch">
    <input message="typens:doGoogleSearch"/>
    <output message="typens:doGoogleSearchResponse"/>
  </operation>
</definitions>
```

Oncogene(MYC):

Found_In_Organism(Human).

Gene_Has_Function(Transcriptional_Regulation).

Gene_Has_Function(Gene_Transcription).

In_Chromosomal_Location(8q24).

Gene_Associated_With_Disease(Burkitts_Lymphoma).

output xsd:complex="RiskType"

```
<owl:Class rdf:about="http://annotation.semanticweb.org/iswc/iswc.daml#RiskIndicator">
```

```
<rdfs:subClassOf>
```

```
<owl:Restriction>
```

```
<owl:onProperty rdf:resource="http://annotation.semanticweb.org/iswc/iswc.daml#name"/>
```

```
<owl:allValuesFrom rdf:resource="http://www.w3.org/2000/10/XMLSchema#string"/>
```

```
</owl:Restriction>
```

```
</rdfs:subClassOf>
```

```
</:Class>
```



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Semantic Web Services

Service composition

File Options

Select a category: **SensorService (14)**

Location

Latitude: in the range

Longitude: greater than

Altitude: equals

Quality: Excellent

Advanced...

Flowchart:

```
graph TD
    SoundIntensity[SoundIntensity] --> RMS[RMS Calculator]
    RMS --> InputWaveFile[InputWaveFile]
    InputWaveFile --> SoundOutput[Sound Output]
    SoundOutput --> FIR[FIR Filter]
    FIR --> WindowType[WindowType]
    FIR --> LowerFreqLimit[Lower FreqLi mit]
    FIR --> UpperFreqLimit[Upper FreqLi mit]
    FIR --> SoundInput[SoundInput]
    WindowType --> UserInput1[User Input]
    LowerFreqLimit --> UserInput2[User Input]
    UpperFreqLimit --> UserInput3[User Input]
    SoundInput --> Services[Services (4/5)]
    UserInput1 --> Rectangular[Rectangular]
    UserInput2 --> InputBox1[]
    UserInput3 --> InputBox2[]

Services (4/5) List:



- Services (4/5) -
- User Input -
- Acoustic Sensor 1
- Acoustic Sensor 2
- Acoustic Sensor 3
- Acoustic Sensor 4



Run

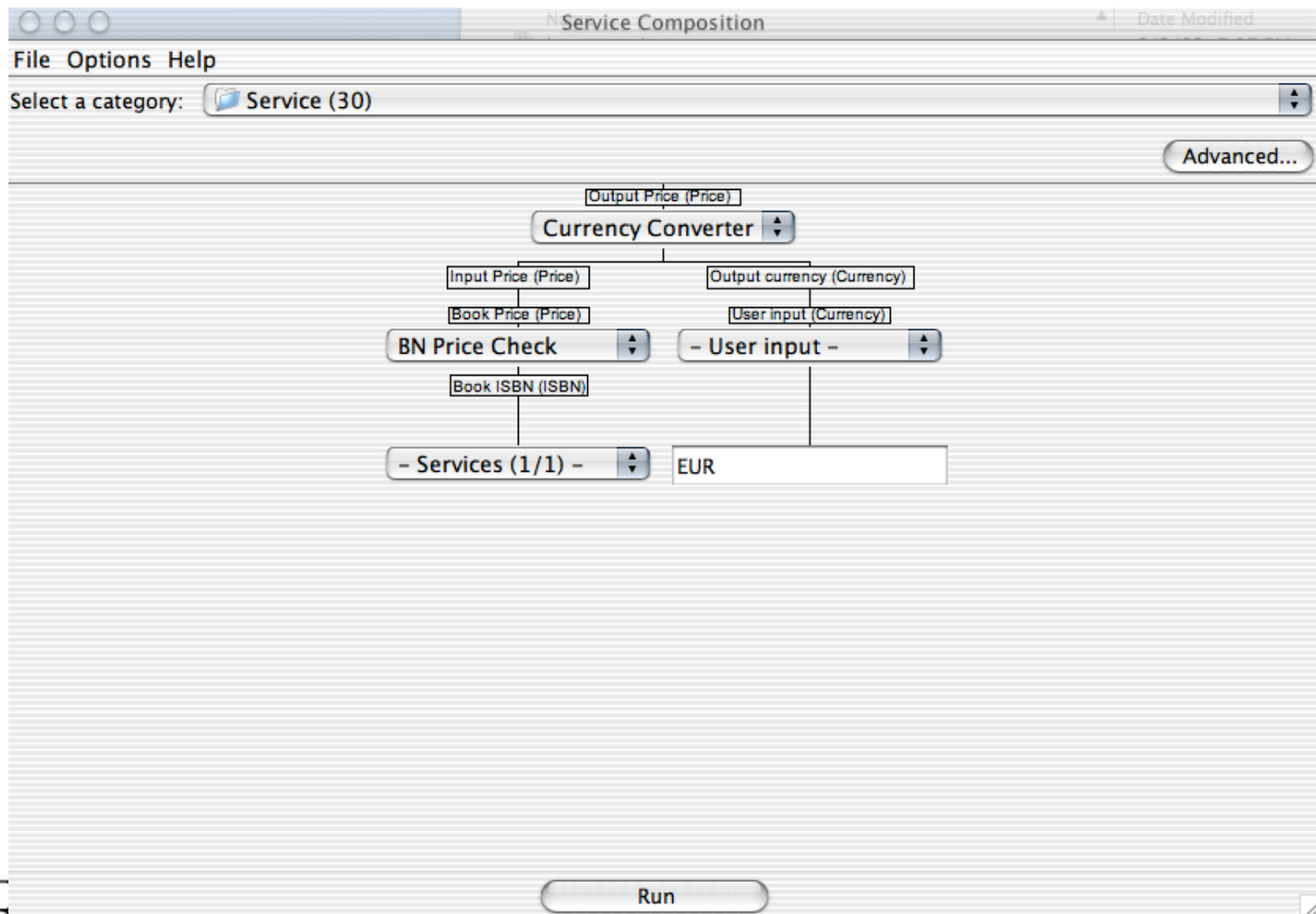

```

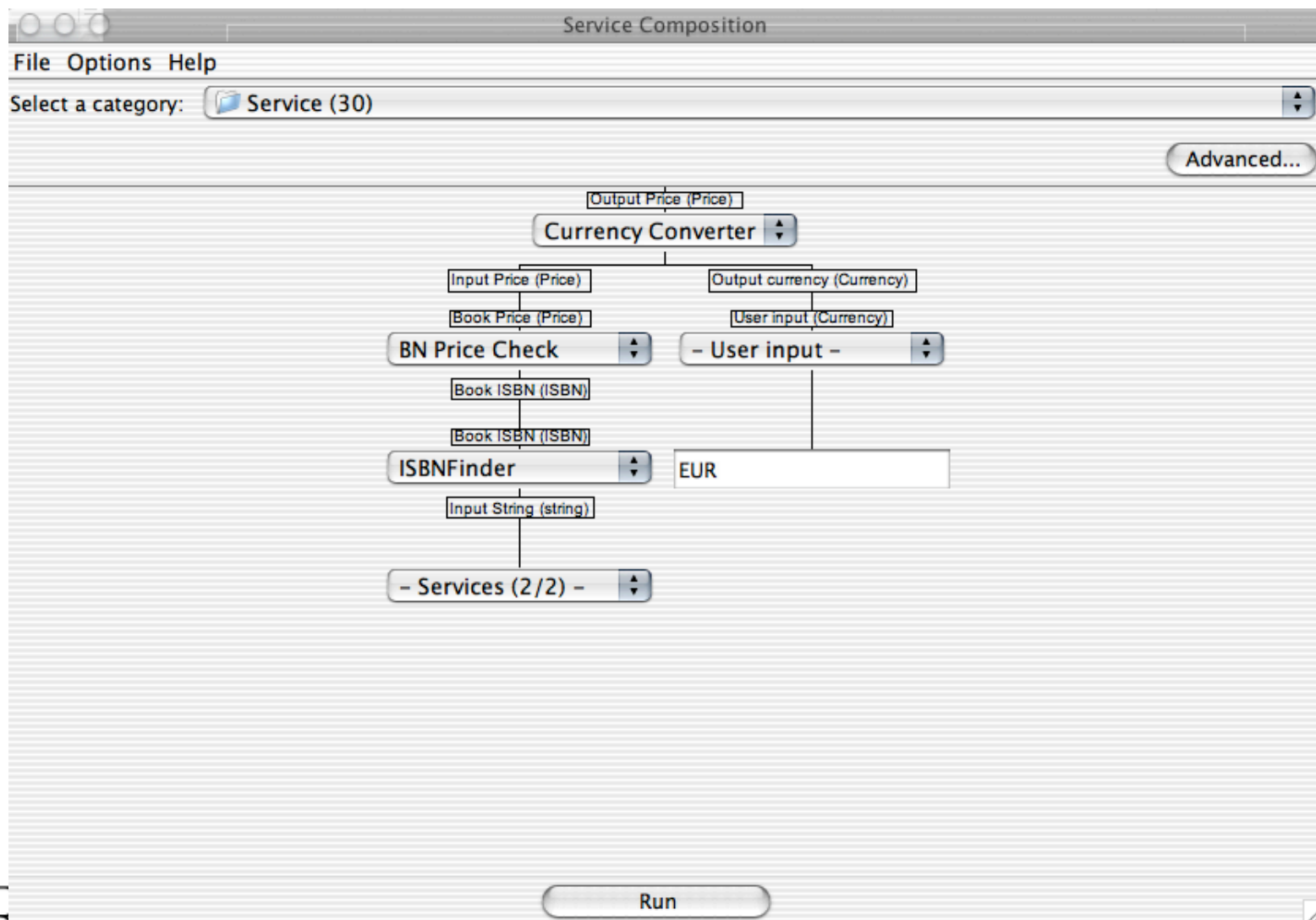


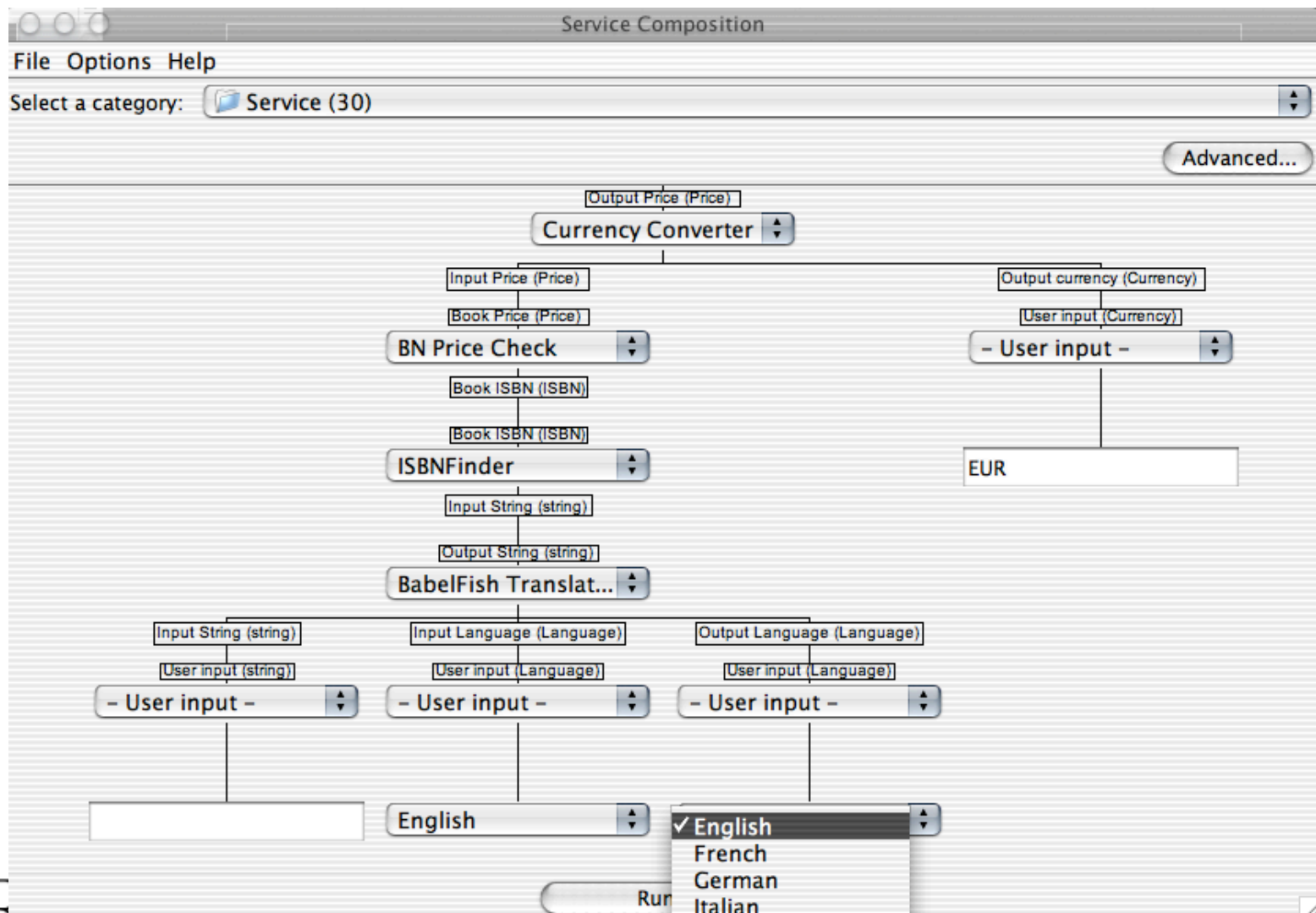
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Advanced information management capabilities
Discovery, Filtering, Composition









Service Composition Execution results

File Options Help

Select a category: **Service (30)**

Current process

Input parameters
Input String = Unix Programmierung

Invoke WSDL Operation findISBN...

Output parameters
Book ISBN = 1565922255

Execute sub-process 2
Execute atomic process CheckBookPrice

Input parameters
Book ISBN = 1565922255

Invoke WSDL Operation getPrice...

Output parameters
Book Price =
Price:
currency: USD
amount: 34.95

Execute sub-process 3
Execute atomic process CheckBookPrice

Input parameters
Input Price =
amount: 34.95
currency: USD
Output currency = EUR

Invoke WSDL Operation convertPrice...

Output parameters
Output Price =
Price:
currency: EUR
amount: 29.948585100000003

Close

Diagram elements:

- Input Price (Price)
- Book Price (Price)
- BN Price Check
- Book ISBN (ISBN)
- ISBNFinder
- Input String (string)
- Output String (string)
- BabelFish Translat.
- Input String (string)
- User input (string)
- User input -
- Unix Programming
- Input Language (Language)
- User input (Language)
- User input -
- English

ICEC, 10/03

100%

Draft

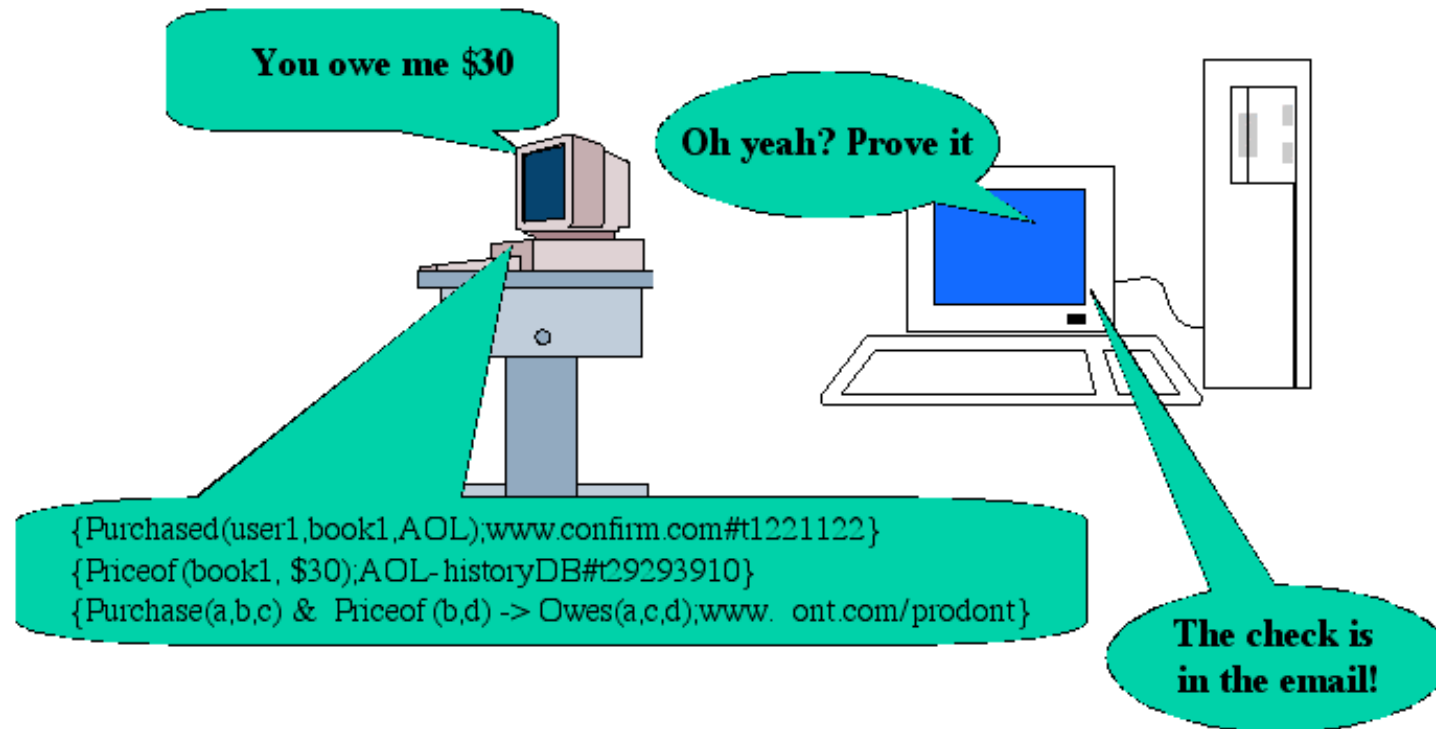


Other capabilities

- Filter based on type of service
- Use of ontology for choosing services
 - filtering based on type or on properties
 - form creation/menu creation from ontology
- Some OWL-S tools for groundings
- Save composition as new service
 - some or all inputs pre-defined
- Generate a “workflow”
 - SOAP messages “disembodied” and run elsewhere



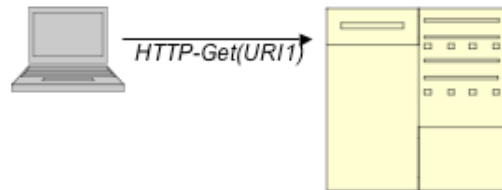
Remember this?



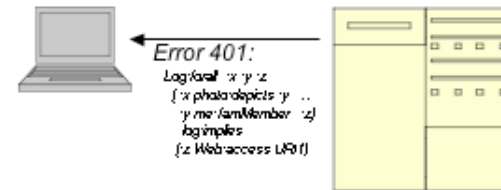
Royal Institute of Technology



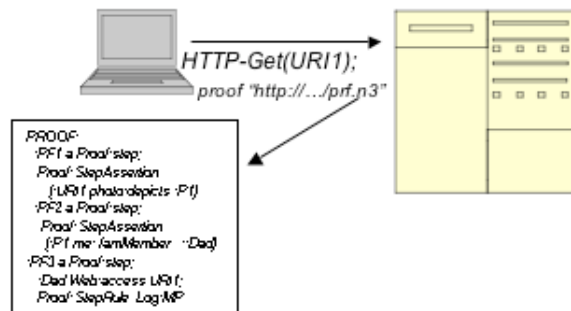
Policy Aware WEB



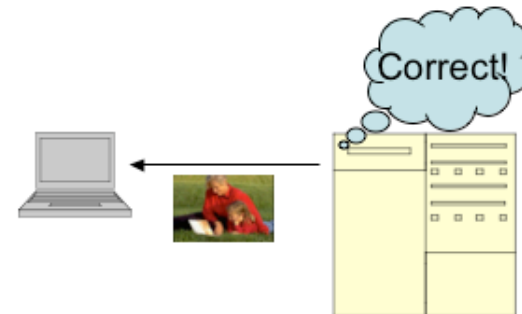
(A) User requests a resource.



(B) 401 error provides access rules.



(C) Proof is generated and pointer is sent in new HTTP-Get request.



(D) Proof is checked, and confirmed, and the transaction succeeds.

NSF ITR: Hendler, Berners-Lee, Weitzner (04-08)



Rensselaer



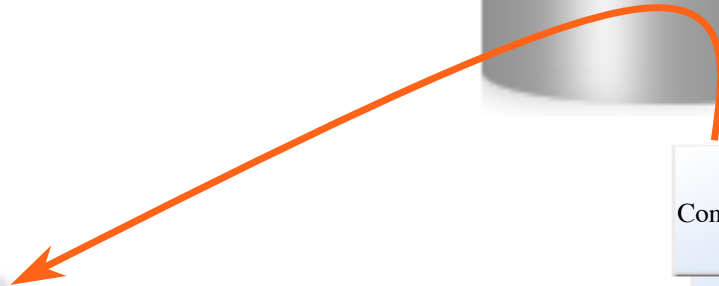
Use case:

A Web browser requests a page and
is given it by a Web server.



Web Server

Content

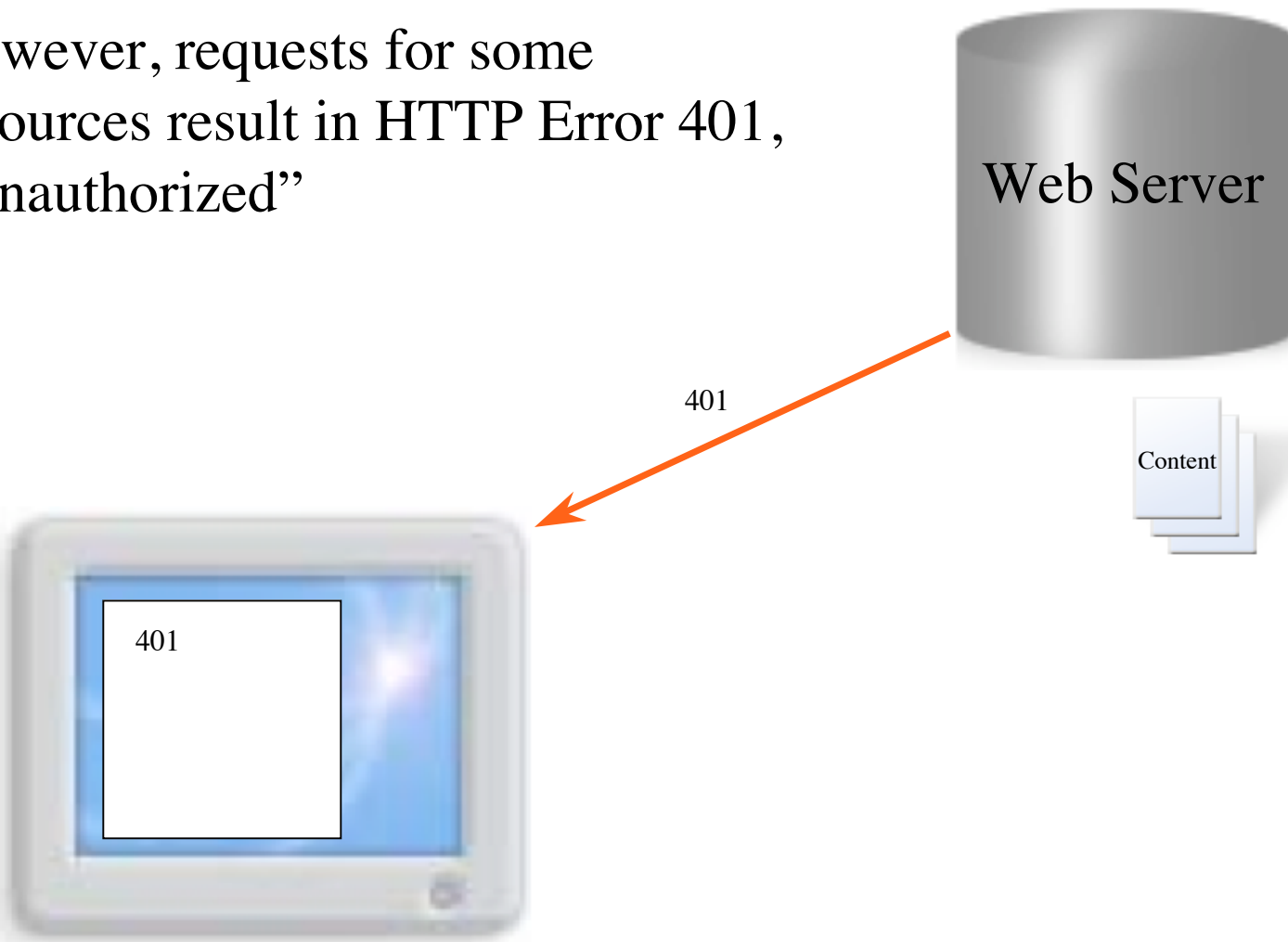


Demo



Tetherless World

However, requests for some resources result in HTTP Error 401, “Unauthorized”



The 401 “Unauthorized” response
has been modified to provide a
URL to a policy:

```
HTTP/1.1 401 Not authorized
Date: Sat, 03 Dec 2005 15:32:18 GMT
Server: TwistedWeb/2.0.1
Policy: http://groups.csail.mit.edu/dig/2005/09/rein/examples/troop42-policy.n3
Content-type: text/html; charset=UTF-8
Connection: close
10:32:20 ERROR 401: Not authorized.
```

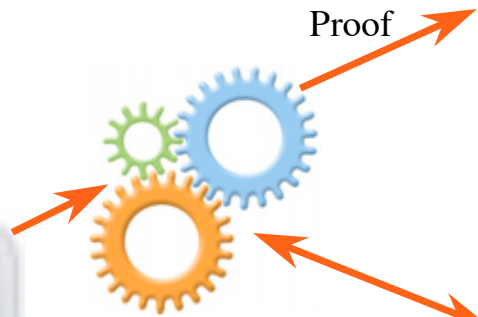


Policies use cwm rules

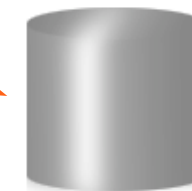
- Cwm
 - Originally developed by Tim Berners-Lee as a forward chaining rules engine for the Semantic Web
 - Based on N3 (formalization in progress)
 - REIN policy engine encoded as cwm rules
 - Cwm extended with proof generator and proof checker

```
{ REQ a rein:Request.  
  REQ rein:resource PHOTO.  
  ?F a TroopStuff; log:includes  
    { PHOTO a t:Photo; t:location LOC.  
      LOC a t:Meeting }.  
  
  REQ rein:requester WHO.  
  WHO session:secret ?S.  
  ?S crypto:md5 TXT.  
  
  ?F a TroopStuff; log:includes  
    { [] t:member [ is foaf:maker of PG ].  
      LOC t:attendee [ is foaf:maker of PG ] }.  
  PG log:semantics [ log:includes  
    { PG foaf:maker [ session:hexdigest TXT ] }  
  ].  
  
} => { WHO http:can-get PHOTO }.
```


Use of the PAW proof-generation proxy results in a proof which satisfies the policy:



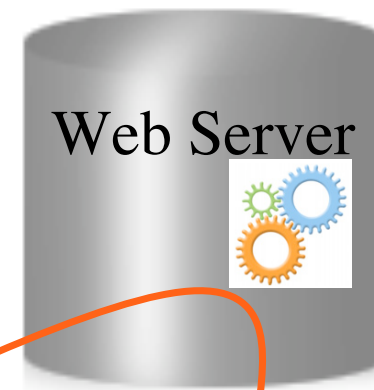
Web Server



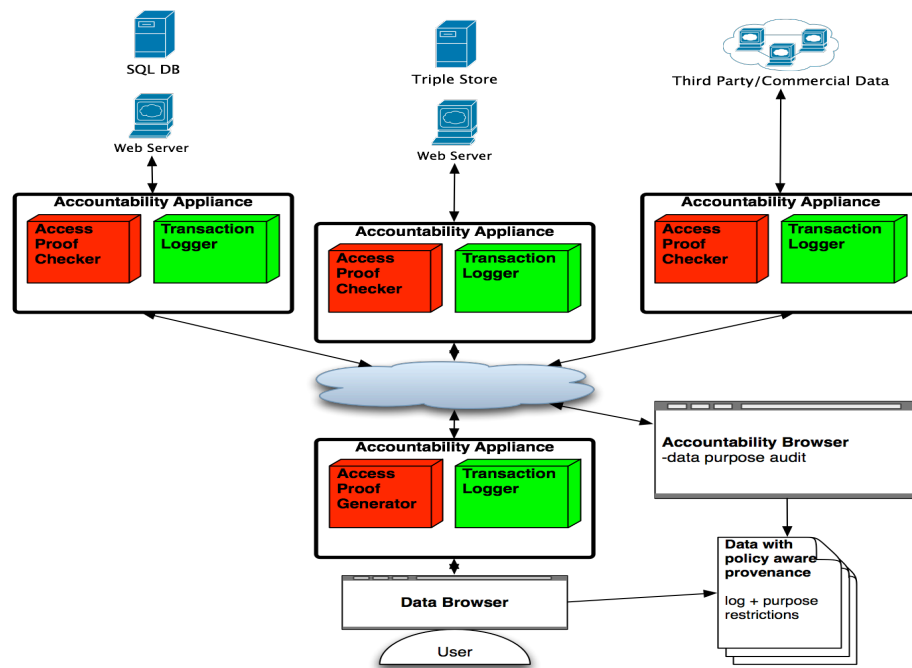
Third-party services may be consulted to help construct the proof.



The Web server checks the proof
and serves the content if it is a valid
and grounded proof.



Accountability architecture



- **Access control through Decentralized Authentication Proofs based on access rules expressed over data semantics**
- ***Transparent* data usage logging for real-time compliance hints and a *posteriori* accountability**
- **Engineered as Web architecture components**

(See CACM - June 2008)



Rensselaer



Summary

- The infrastructure needs of intelligent systems are now being met by a combination of Semantic Web, Linked Data, Web Services and Rule-based systems
 - Knowledge engineering can be jumpstarted from existing terminologies/ontologies, semi-structured systems, and other Web resources
 - Web Services (esp WSDL, SAWSDL) provide "wrappers" and other methods to let "legacy" systems play with agents
 - Reasoners and rule-based systems are scaling in new ways, and receiving some standardization
- So where are all the agents???