Where are all the Intelligent ^ 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…

Jim Hendler
Chief Scientist - Information Systems Office
DARPA

http://www.daml.org

Slides from a May 2001 talk

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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

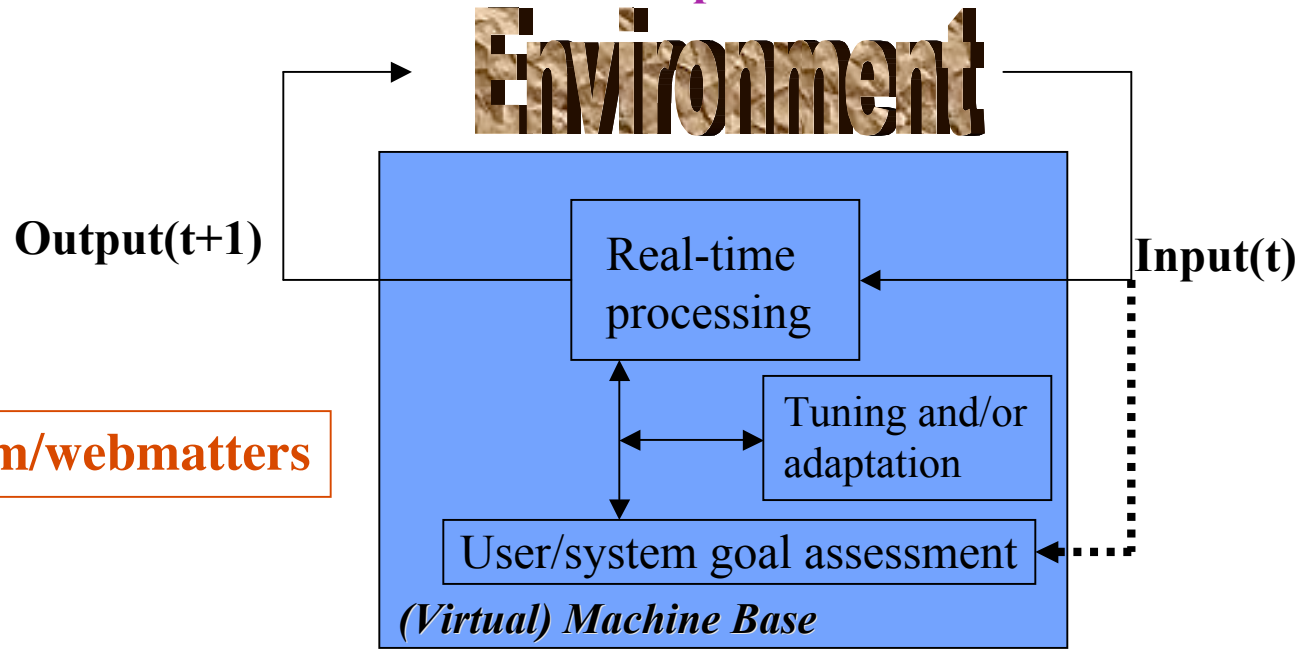
Complexity

Autonomous

Communicative

Capable

Adaptive



Http://helix.nature.com/webmatters

Beyond XML:Agent Semantics

- **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/jhendler/agents.html">

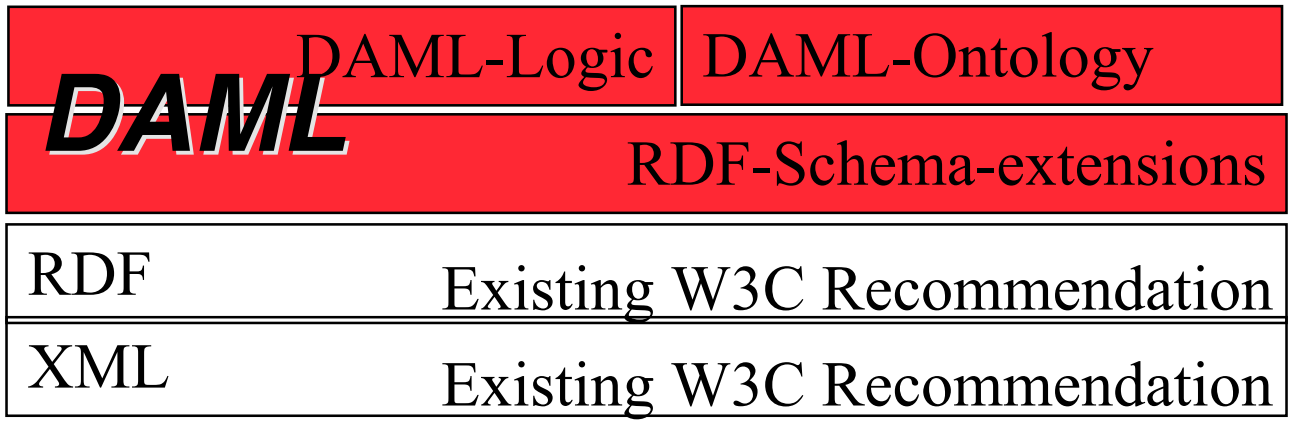
<RELATION-VALUE POS1 = “Agents” POS2 = “/jhendler”>

<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

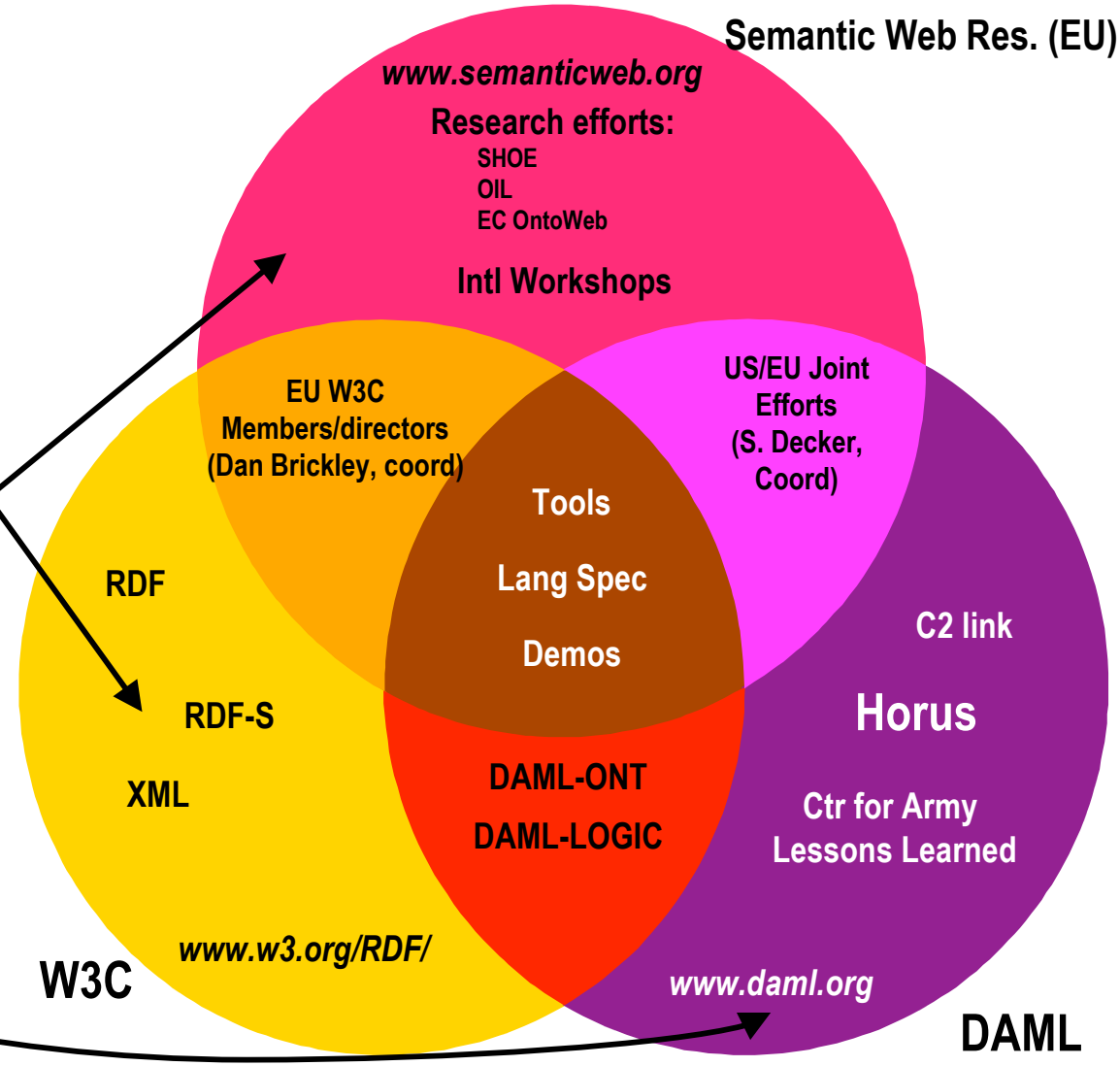


- DAML is being built on existing web "standards", by many of the same people who developed them
  - PI Team includes MIT researchers who also head up World Wide Web Consortium:
    - PI/Co-PI: Tim Berners-Lee, Ralph Swick, Dan Connolly

DAML
Technical Approach

DARPA:

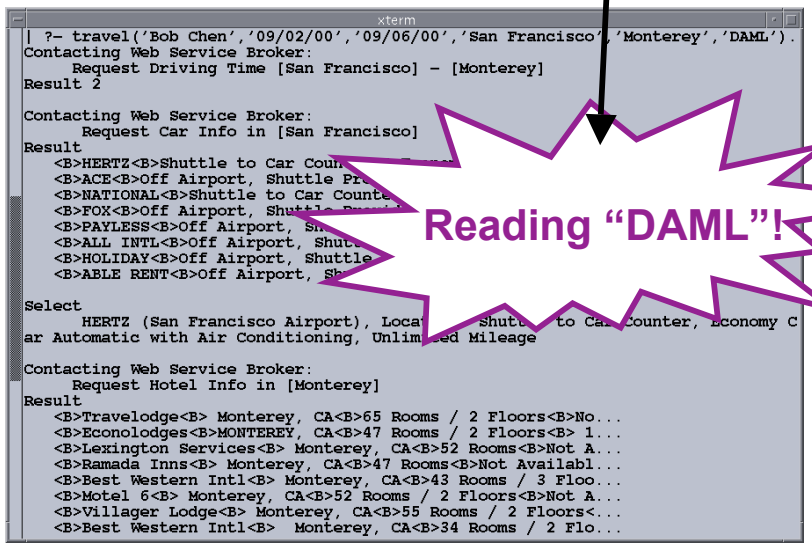
- **Funds a new generation of www technology**
  - Works closely with W3C to create a web standard
  - Works closely with EU on international acceptance
- **Brings DoD users (J2,J3,J6) in as early adopters**



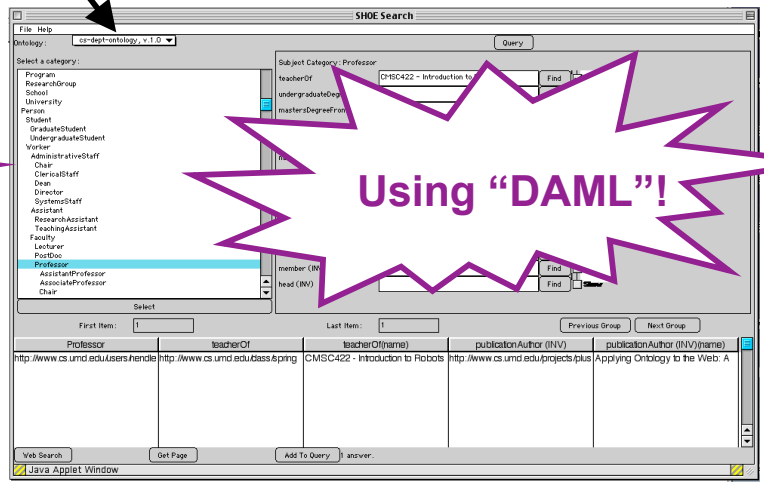
DAML Examples

- "Transparent" Markup
- Content-Based Search
- Service advertising

Writing "DAML"!



Reading "DAML"!



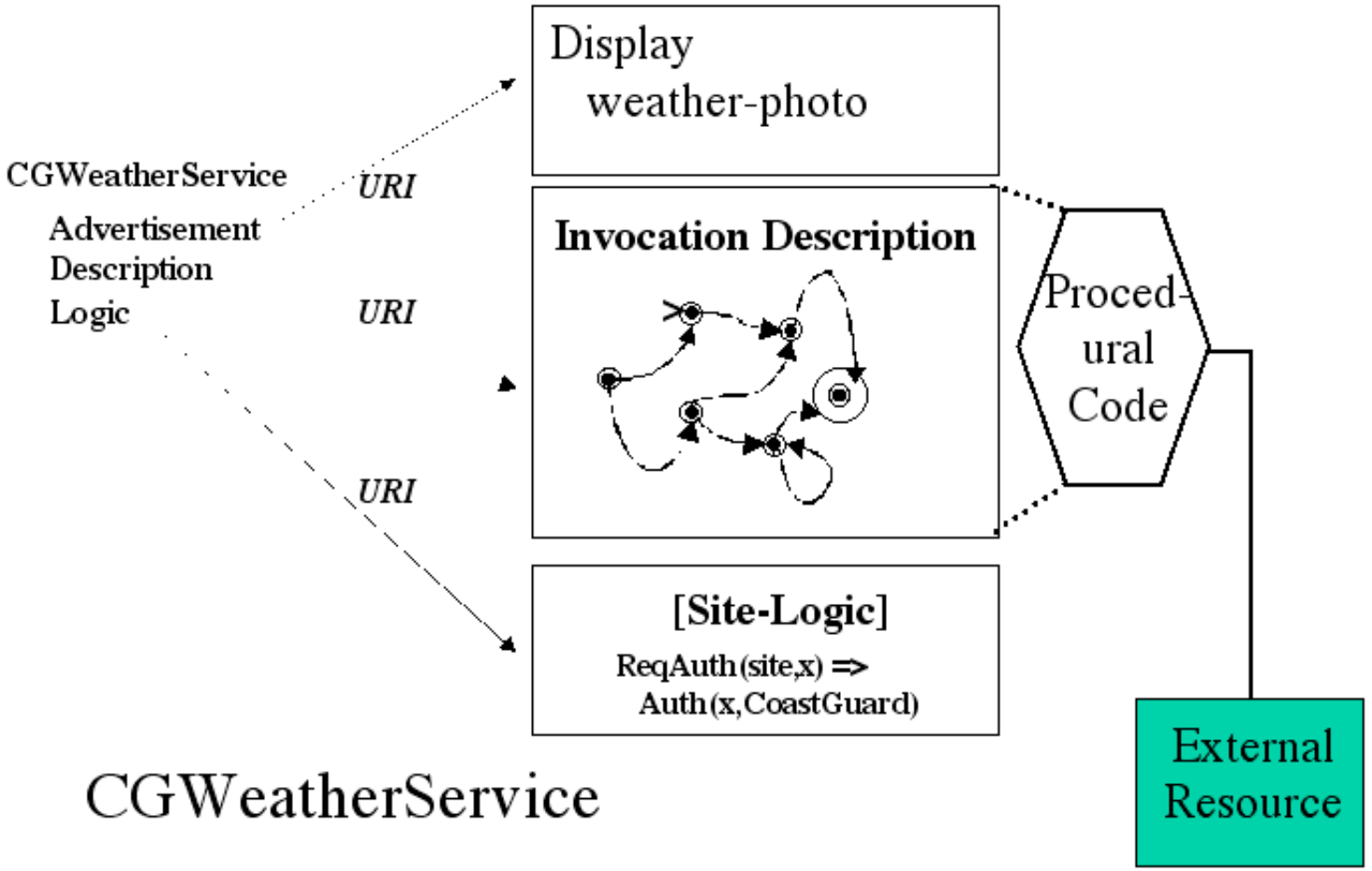
Using "DAML"!

Web "travel" agents

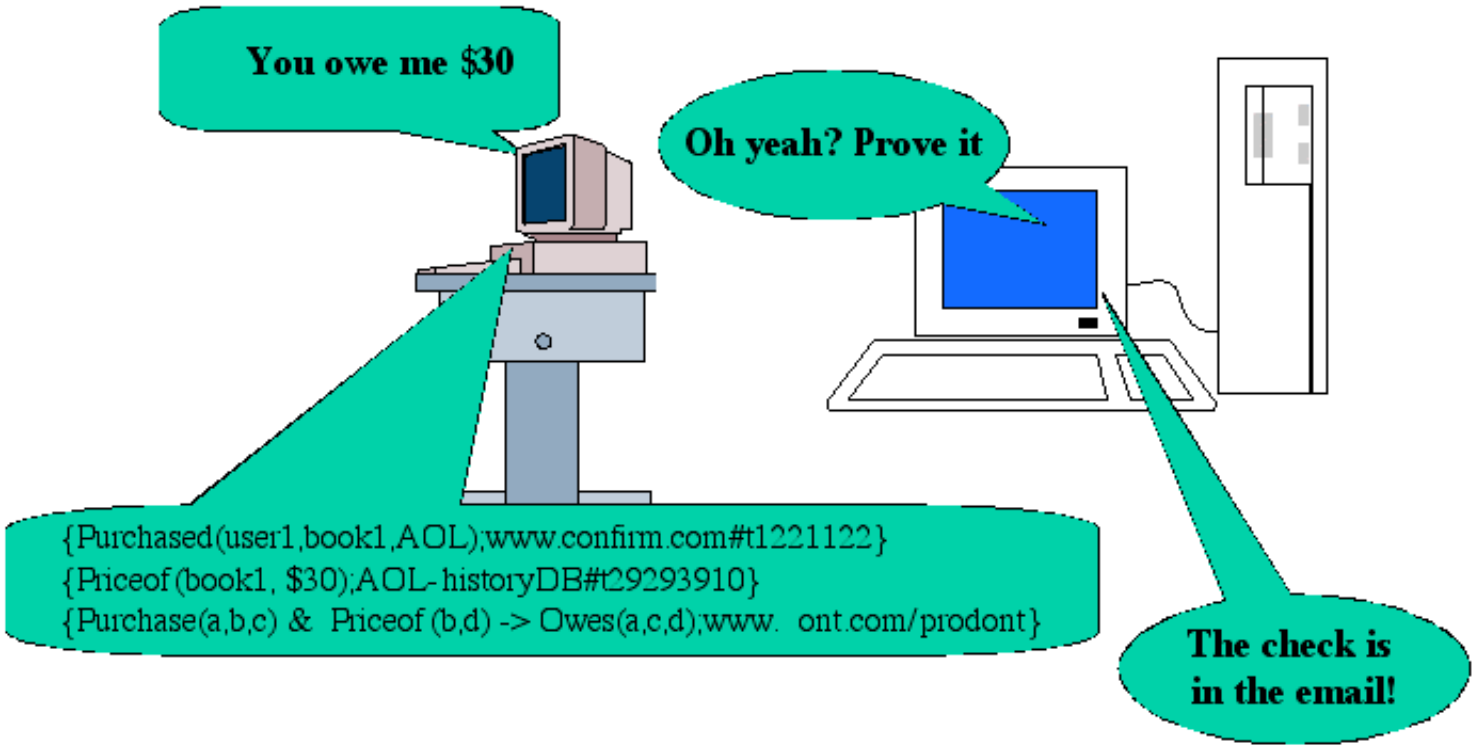
Query processed:

- 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 satelite images" is advertised as becoming available in 2004. See http://… for more information

Service Descriptions



Web Logics


You owe me $30
Oh yeah? Prove it
{Purchased(user1,book1,AOL);www.confirm.com#t1221122}
{Priceof(book1, $30);AOL-historyDB#t29293910}
{Purchase(a,b,c) & Priceof(b,d) -> Owes(a,c,d);www. ont.com/prodont}
The check is in the email!

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

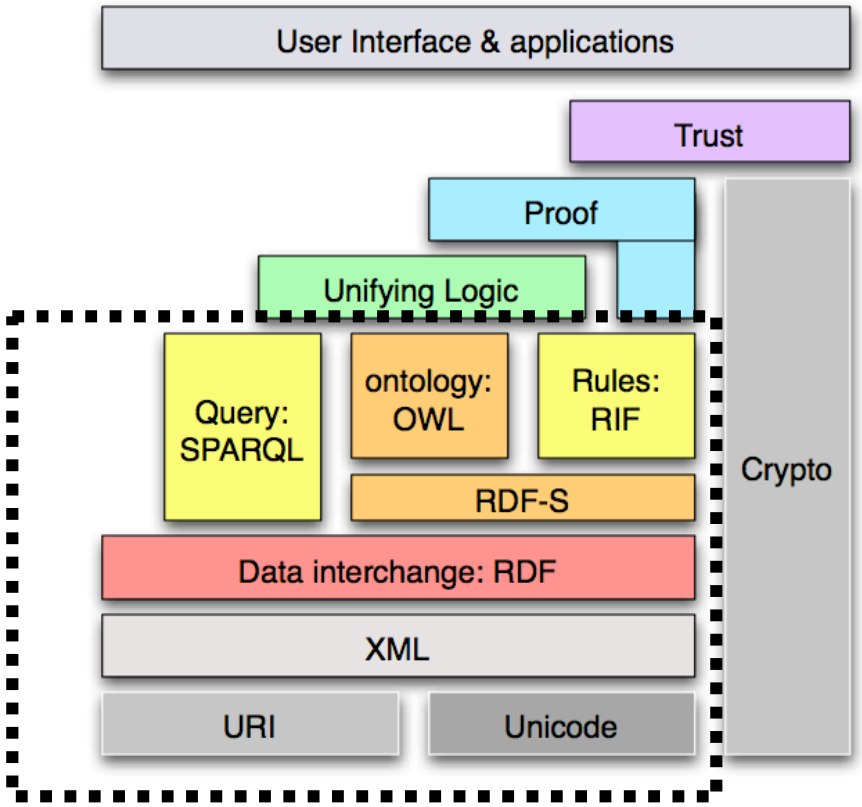
So where are all the agents?

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, …

Semantic Web "Stack"

Standards



ca. 2006 (Tim Berners-Lee)

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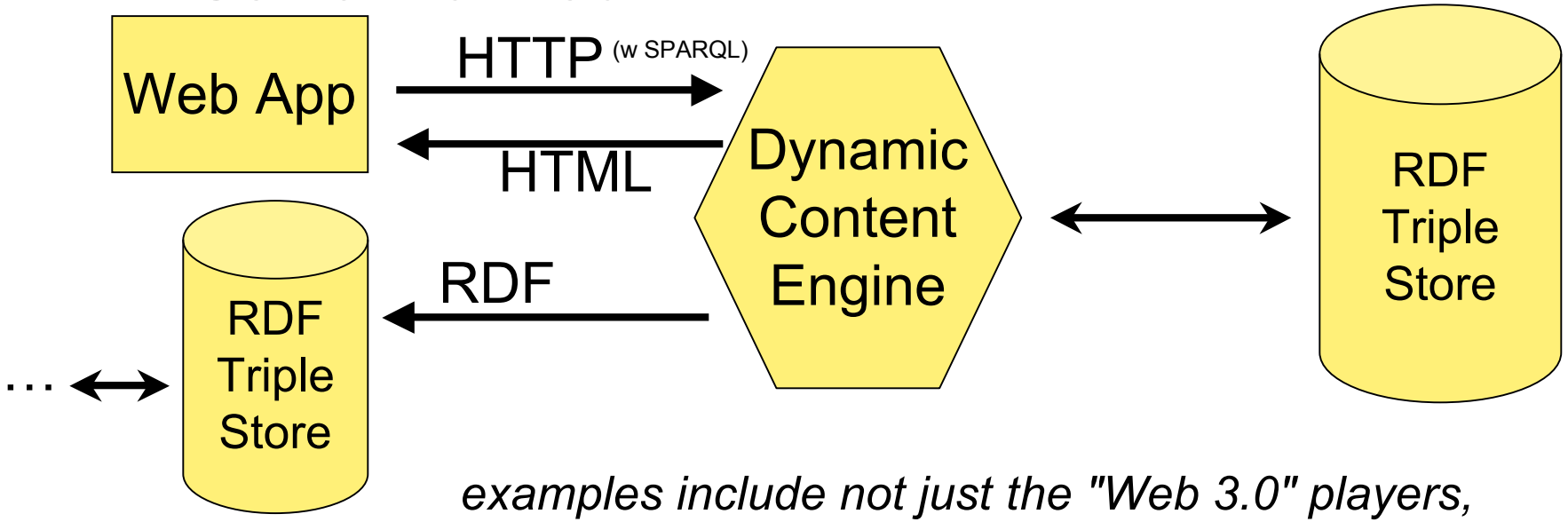
Agents opportunity: "Web 3.0"

- 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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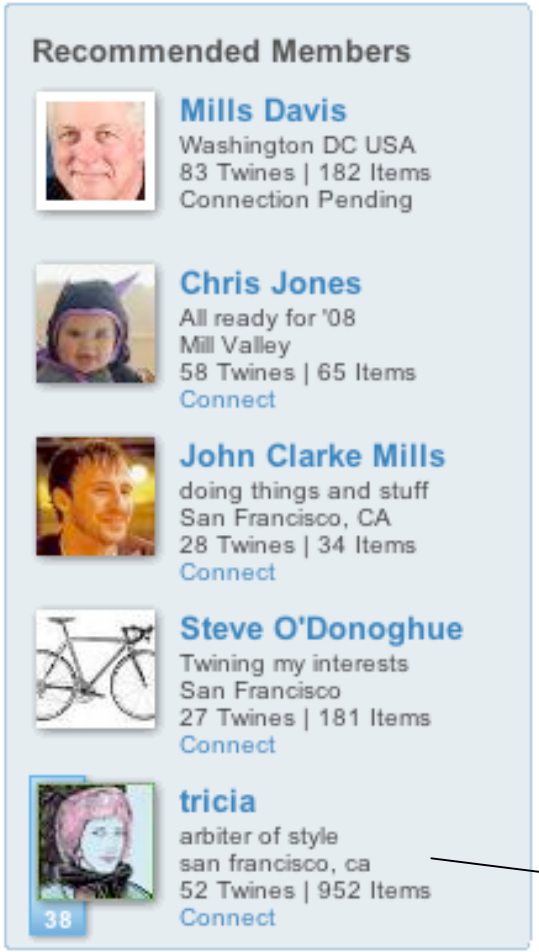
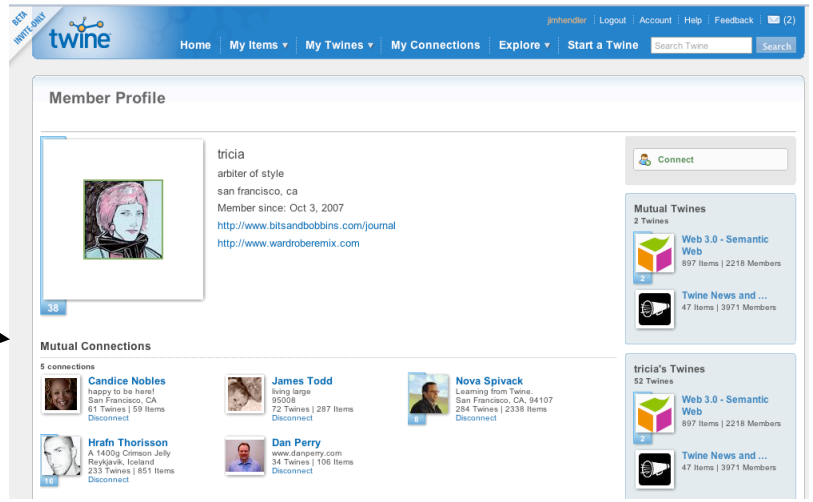
Agent-like needs



- 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



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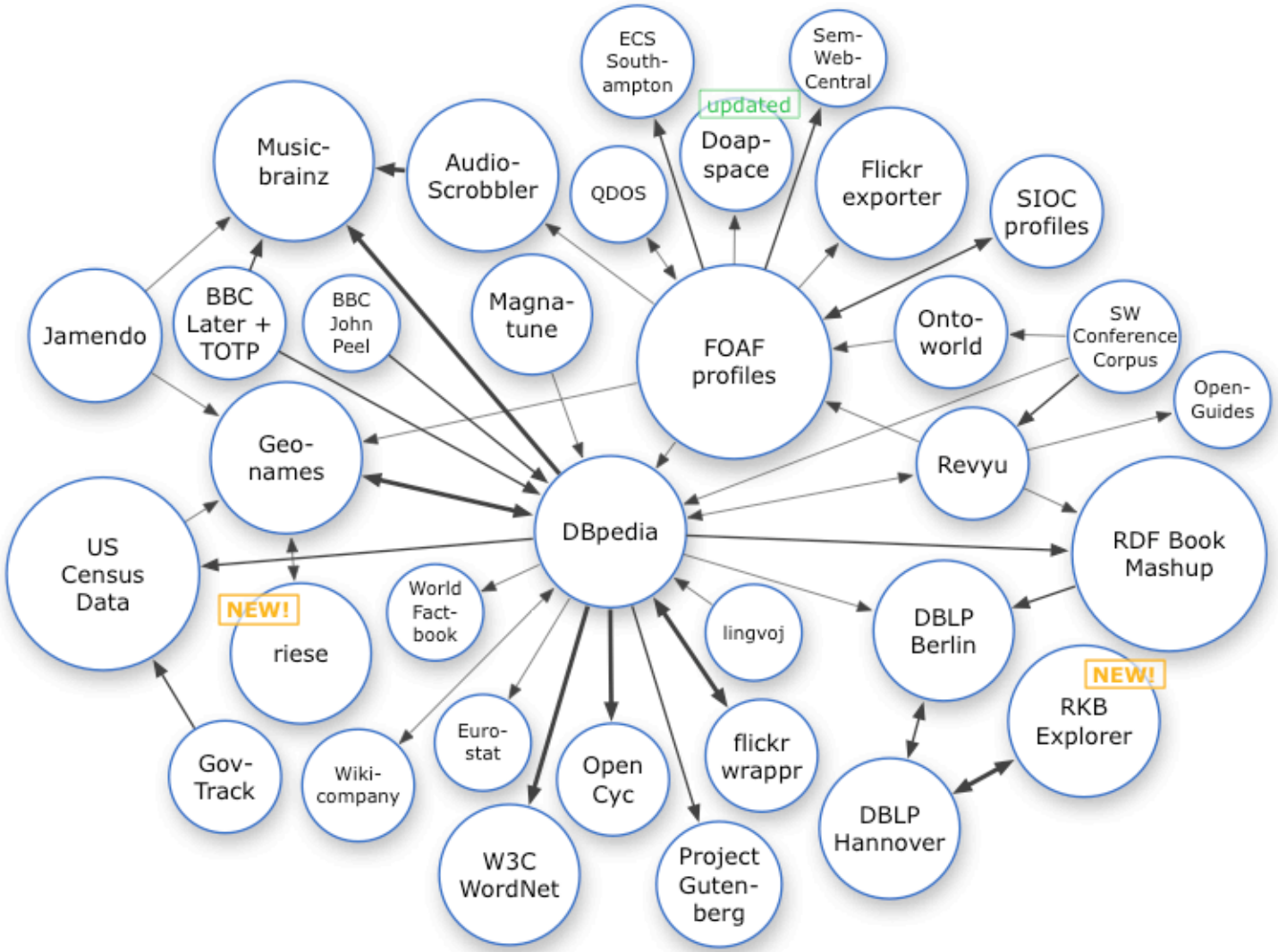

The linked open data cloud now has billions of assertions, and is growing rapidly

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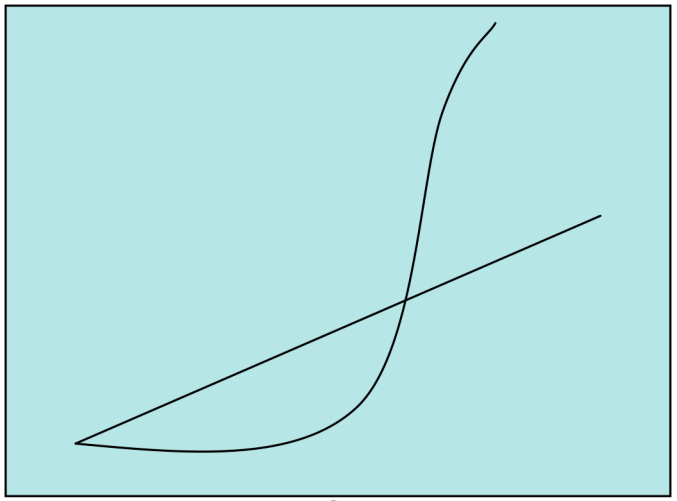
Linking is power

- 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

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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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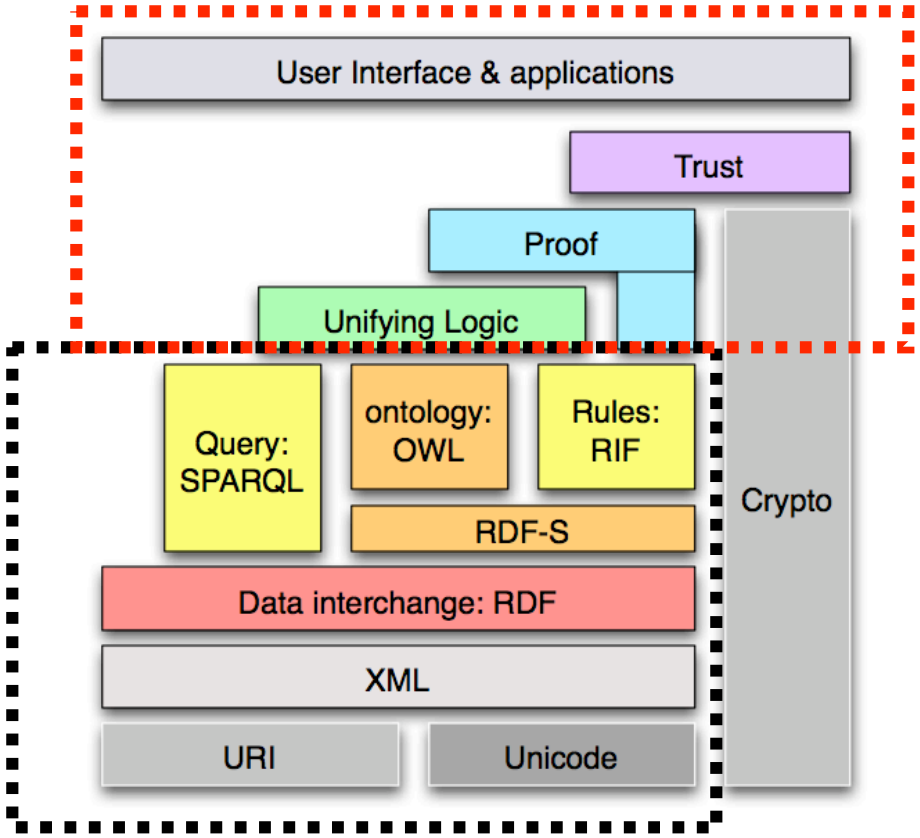
Wine Agent, next steps

- 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"



Research Activities

Standards activities

ca. 2006 (Tim Berners-Lee)

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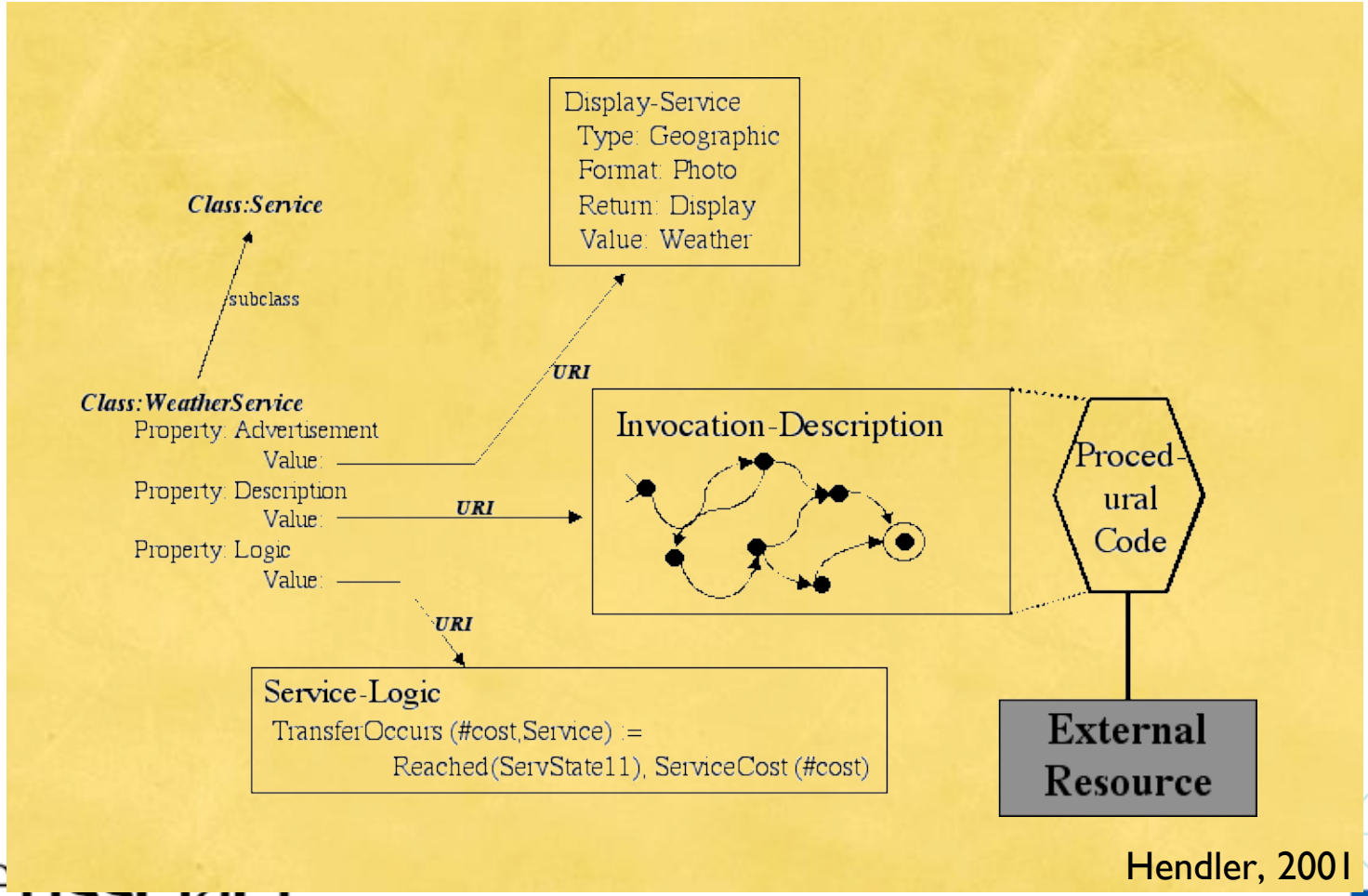
Web Agents need Service Descriptions



Hendler, 2001

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>
```

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Grounding WSDL

input xsd:complex="oncogene"

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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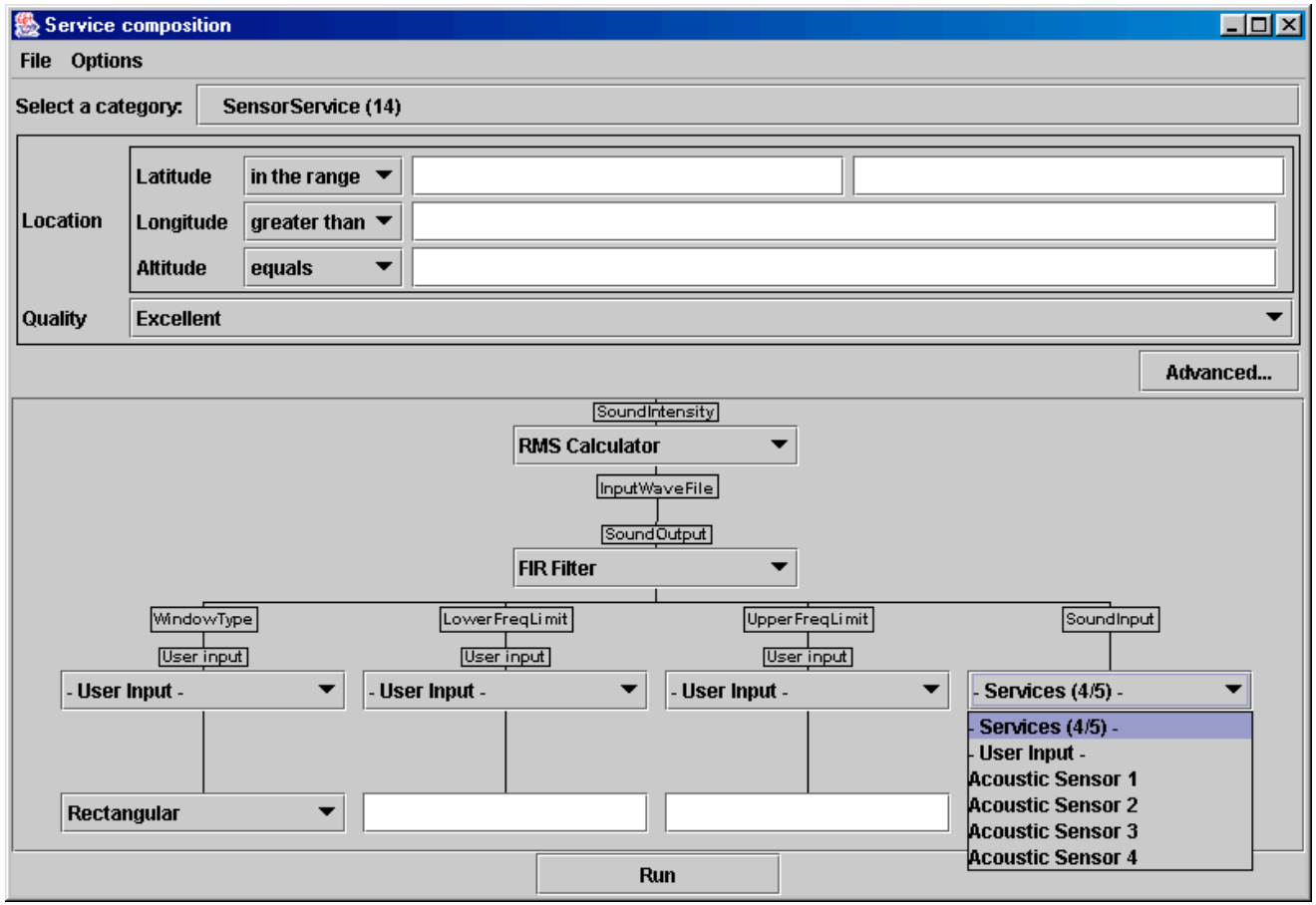
Semantic Web Services



Advanced information management capabilities
Discovery, Filtering, Composition

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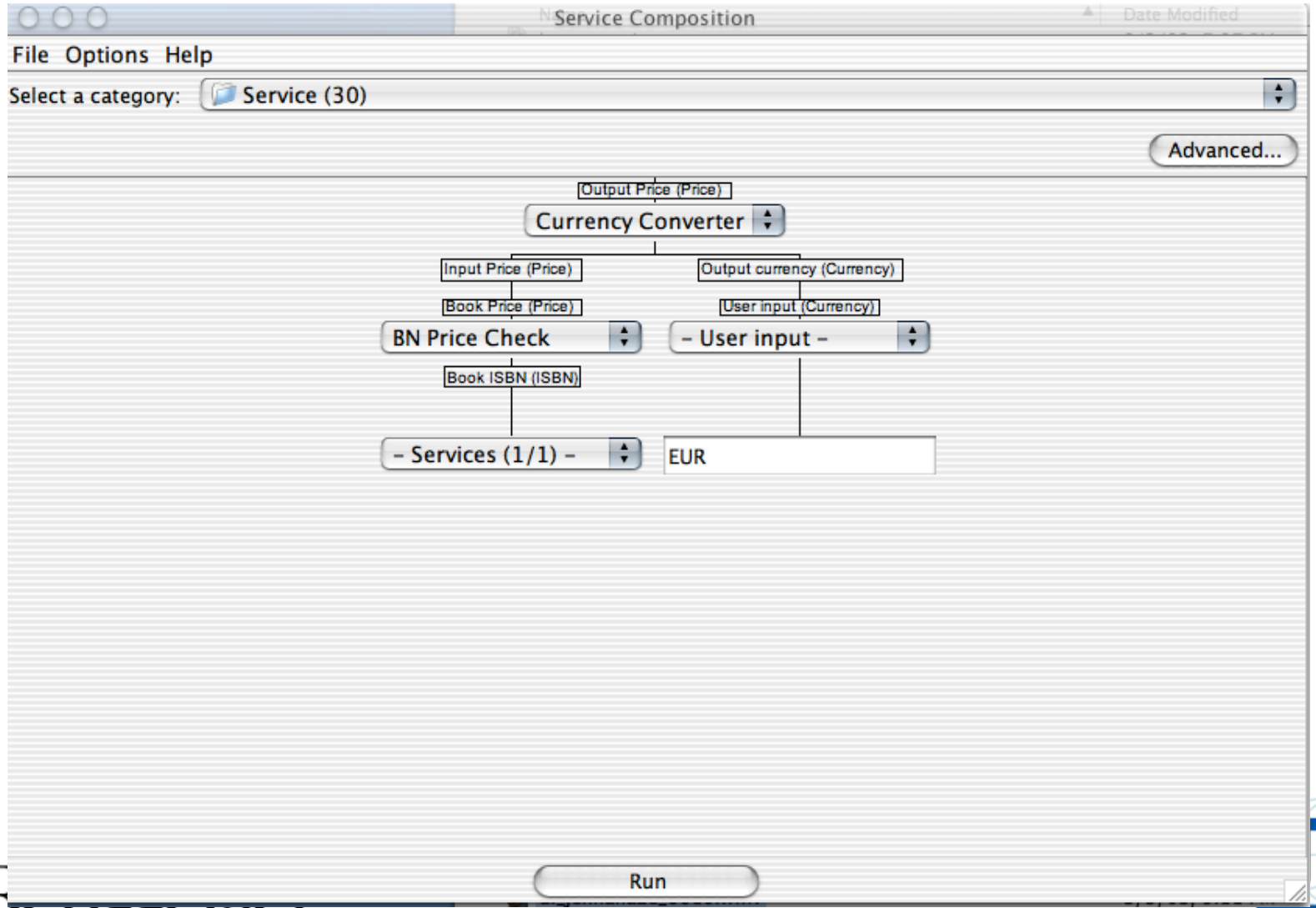
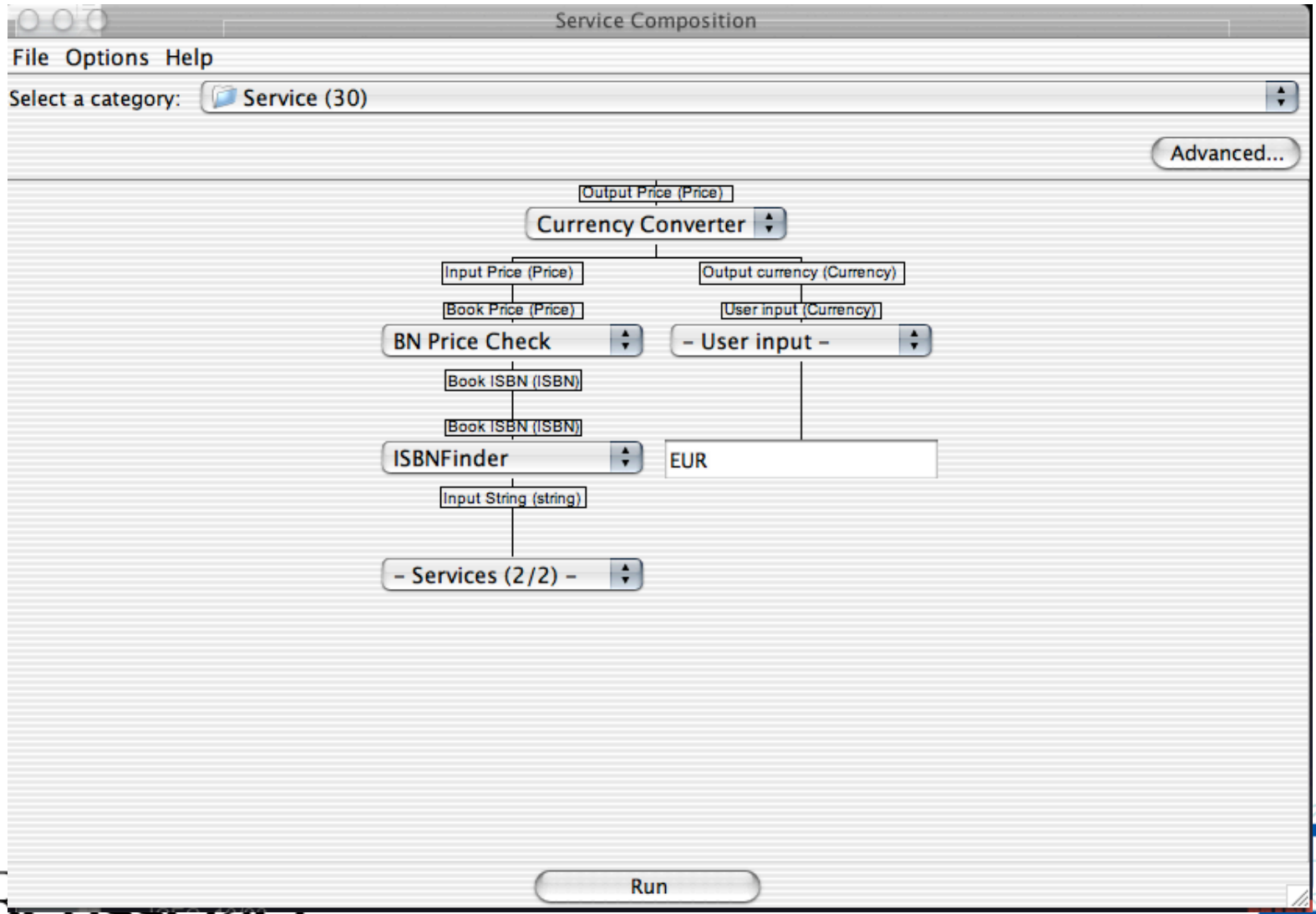
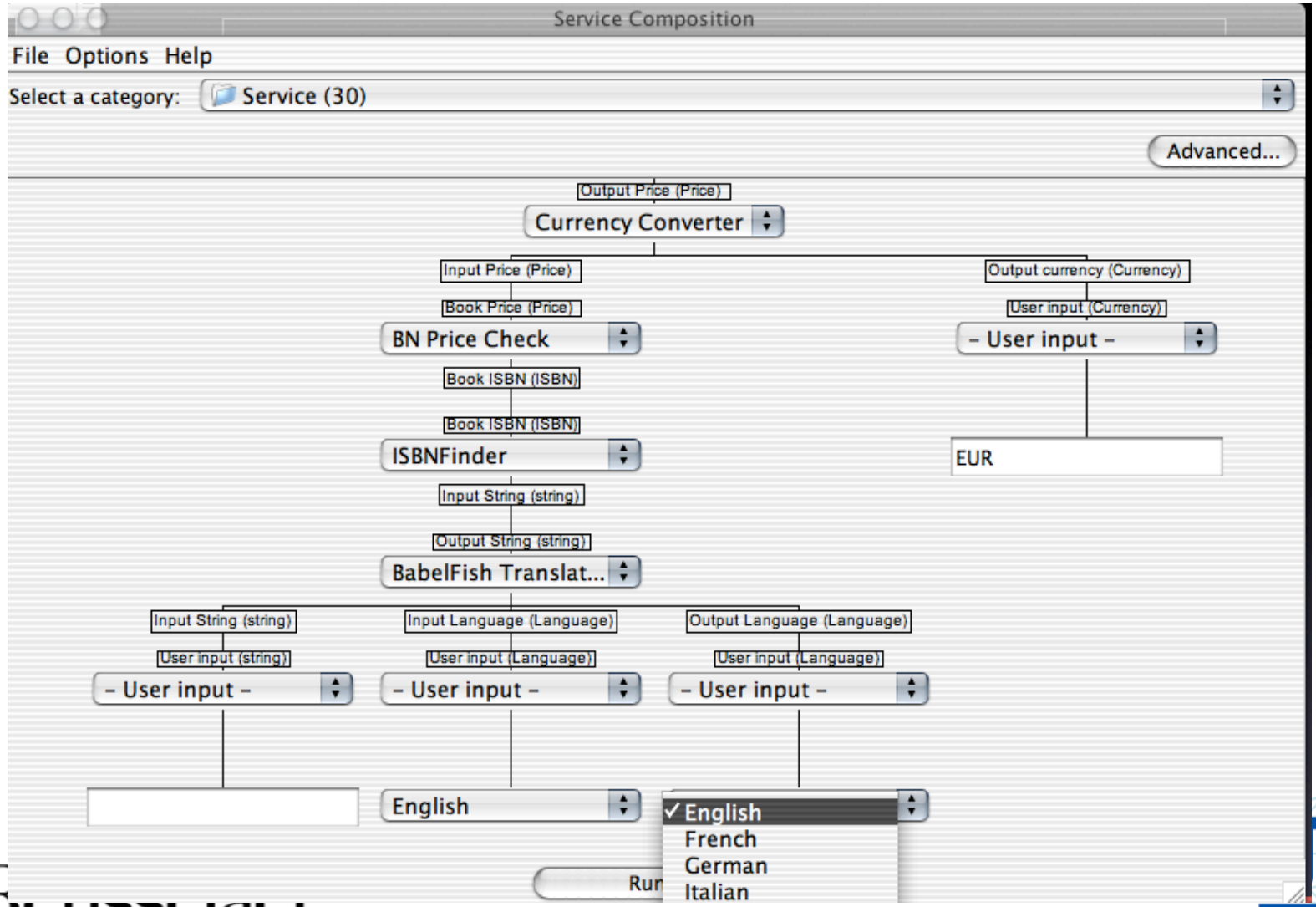
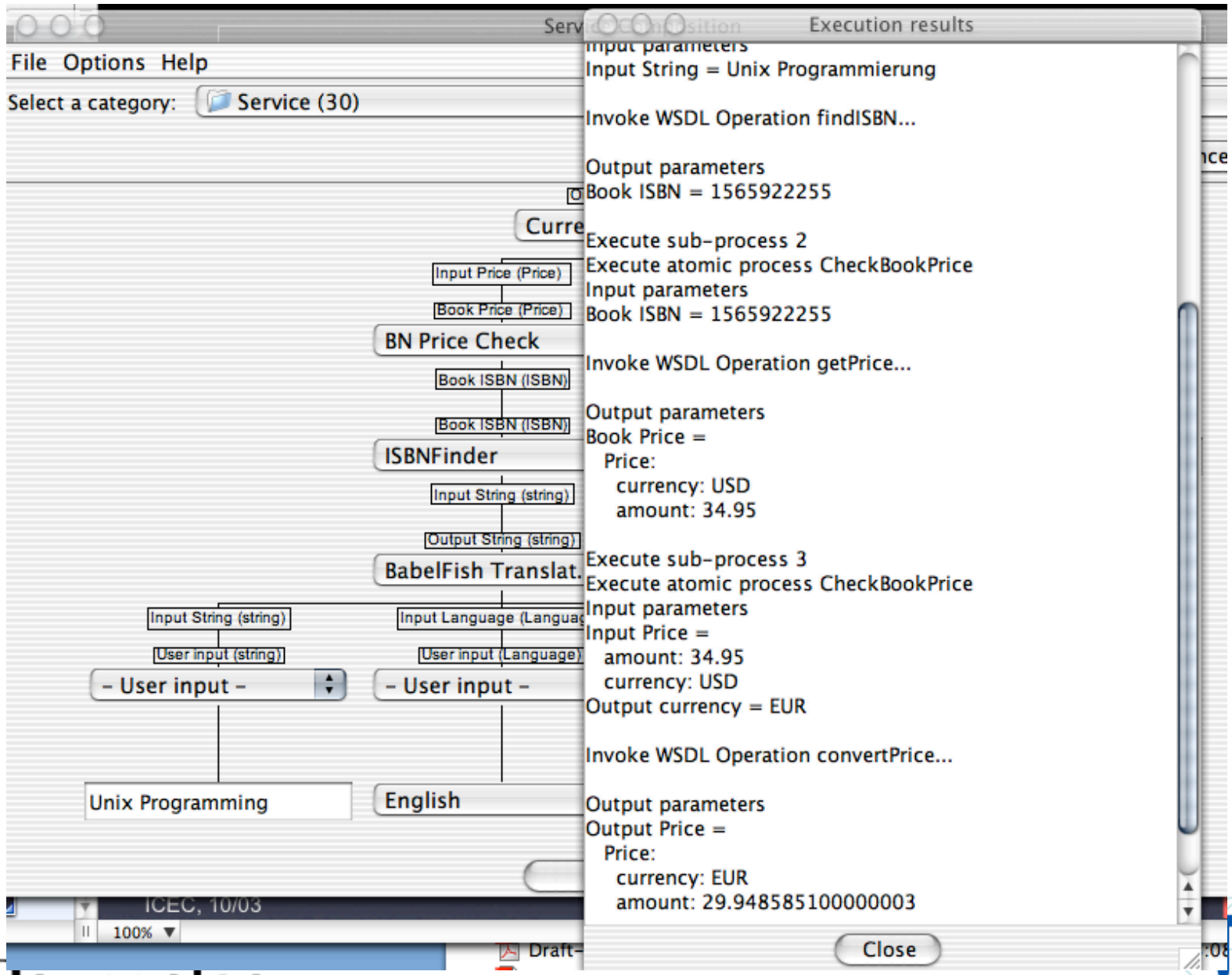

Service Composition
File Options Help
Select a category:
Service (30)
Advanced...
Output Price (Price)
Currency Converter
Input Price (Price)
Output currency (Currency)
Book Price (Price)
User input (Currency)
BN Price Check
- User input -
Book ISBN (ISBN)
- Services (1/1) -
EUR
Run


Service Composition
File Options Help
Select a category:
Service (30)
Advanced...
Output Price (Price)
Currency Converter
Input Price (Price)
Output currency (Currency)
Book Price (Price)
User input (Currency)
BN Price Check
– User input –
Book ISBN (ISBN)
Book ISBN (ISBN)
ISBNFinder
EUR
Input String (string)
– Services (2/2) –
Run

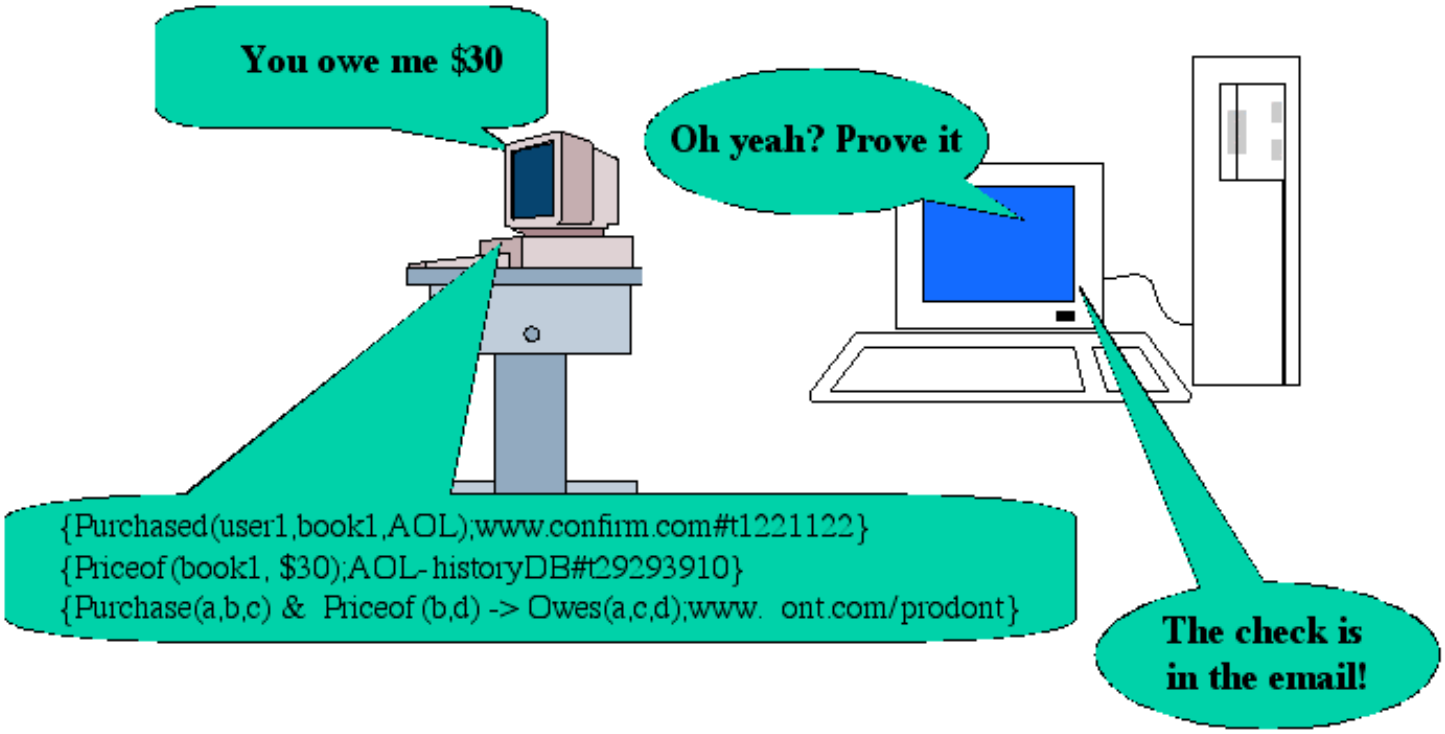



File Options Help
Select a category:
Service (30)
Input Price (Price)
Book Price (Price)
BN Price Check
Book ISBN (ISBN)
Book ISBN (ISBN)
ISBNFinder
Input String (string)
Output String (string)
BabelFish Translat.
Input String (string)
Input Language (Languag
User input (string)
User input (Language)
- User input -
- User input -
Unix Programming
English
ICEC, 10/03
100%
Execution results
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

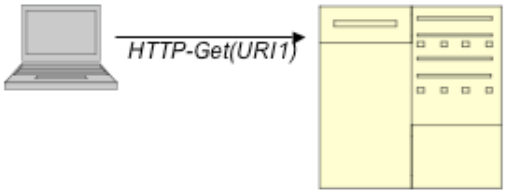
Other capabilities

- 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

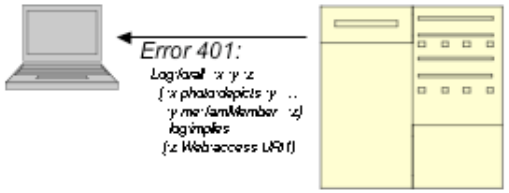
Remember this?



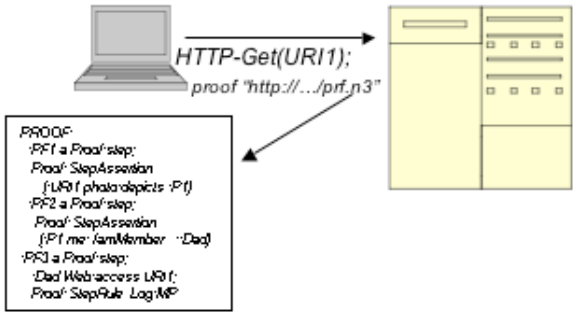
Policy Aware WEB



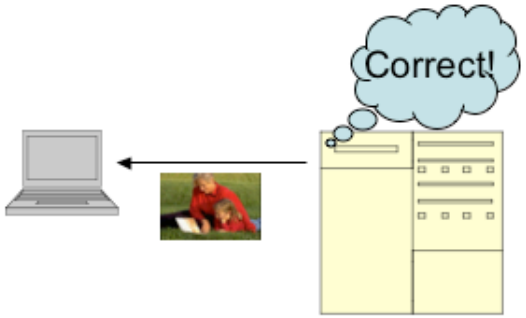
(A) User requests a resource.



(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)

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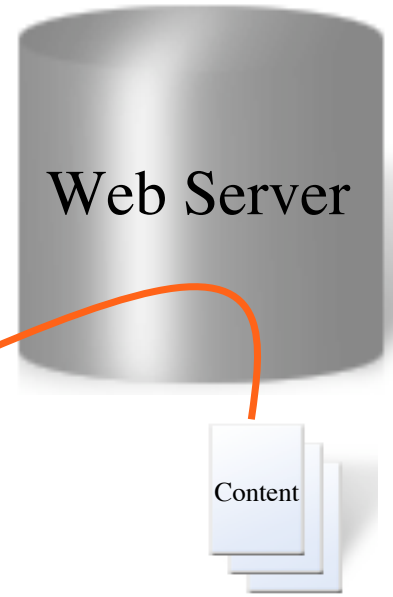
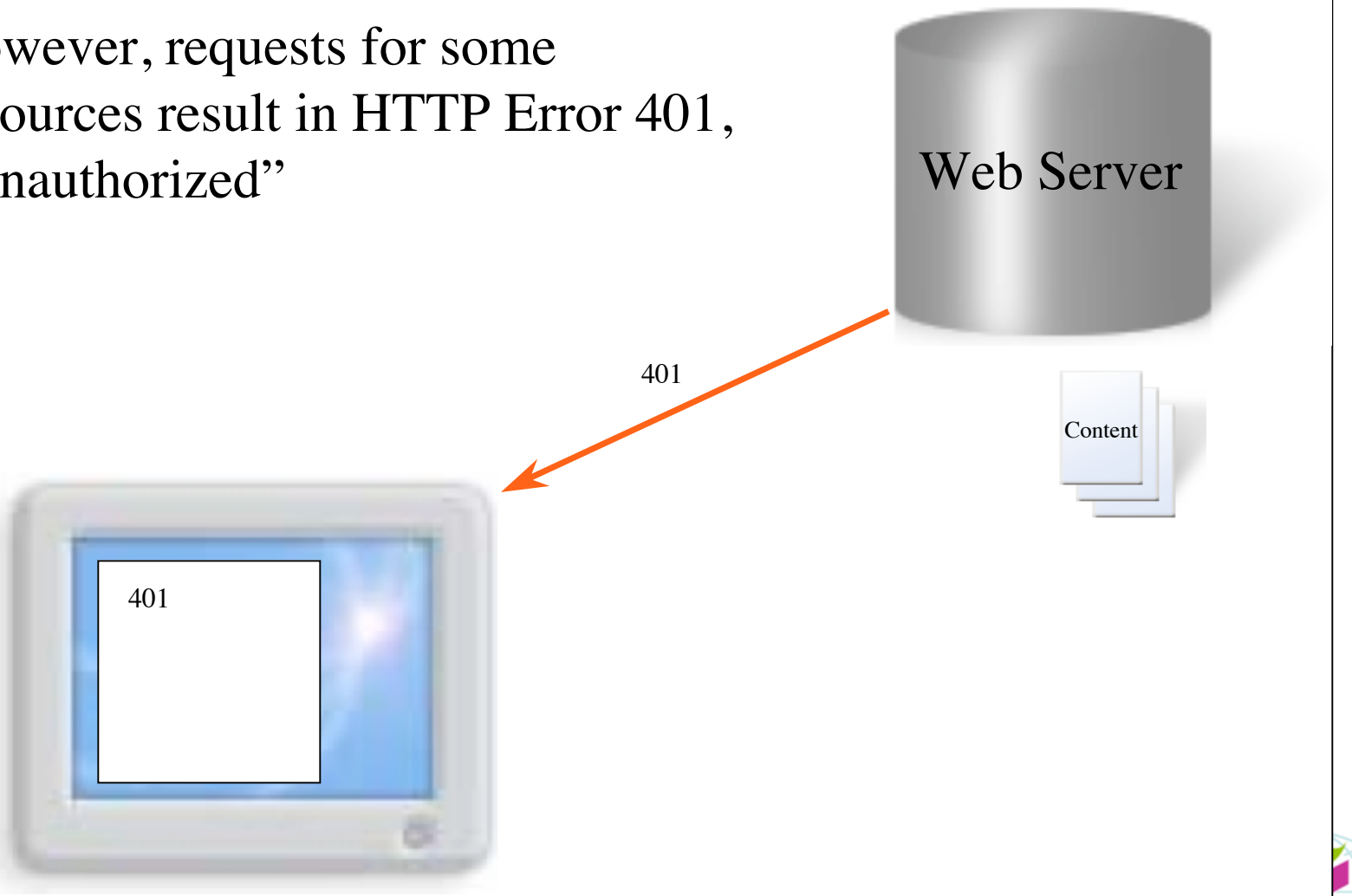
Use case:
A Web browser requests a page and is given it by a Web server.



Demo

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:

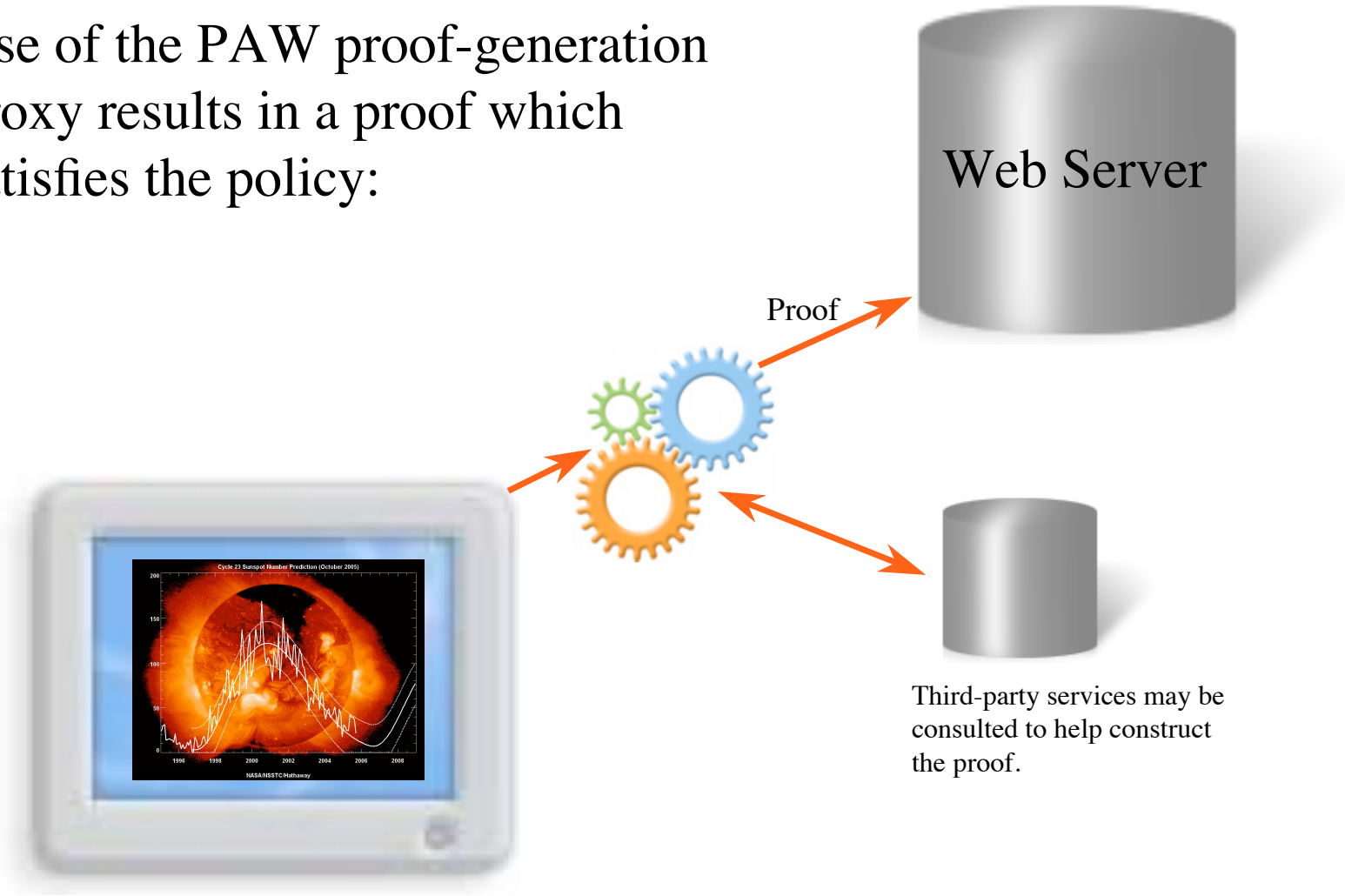
```
HTTP/1.1 401 Not authorized
 Date: Sat, 03 Dec 2005 15:32:18 GMT
 Server: TwistedWeb/2.0.1
 Policy: http://groups.csail.mit.edu/dig/2005/09/rein/examples/troop42-policy.n3
 Content-type: text/html; charset=UTF-8
 Connection: close
10:32:20 ERROR 401: Not authorized.
```

Policies use cwm rules

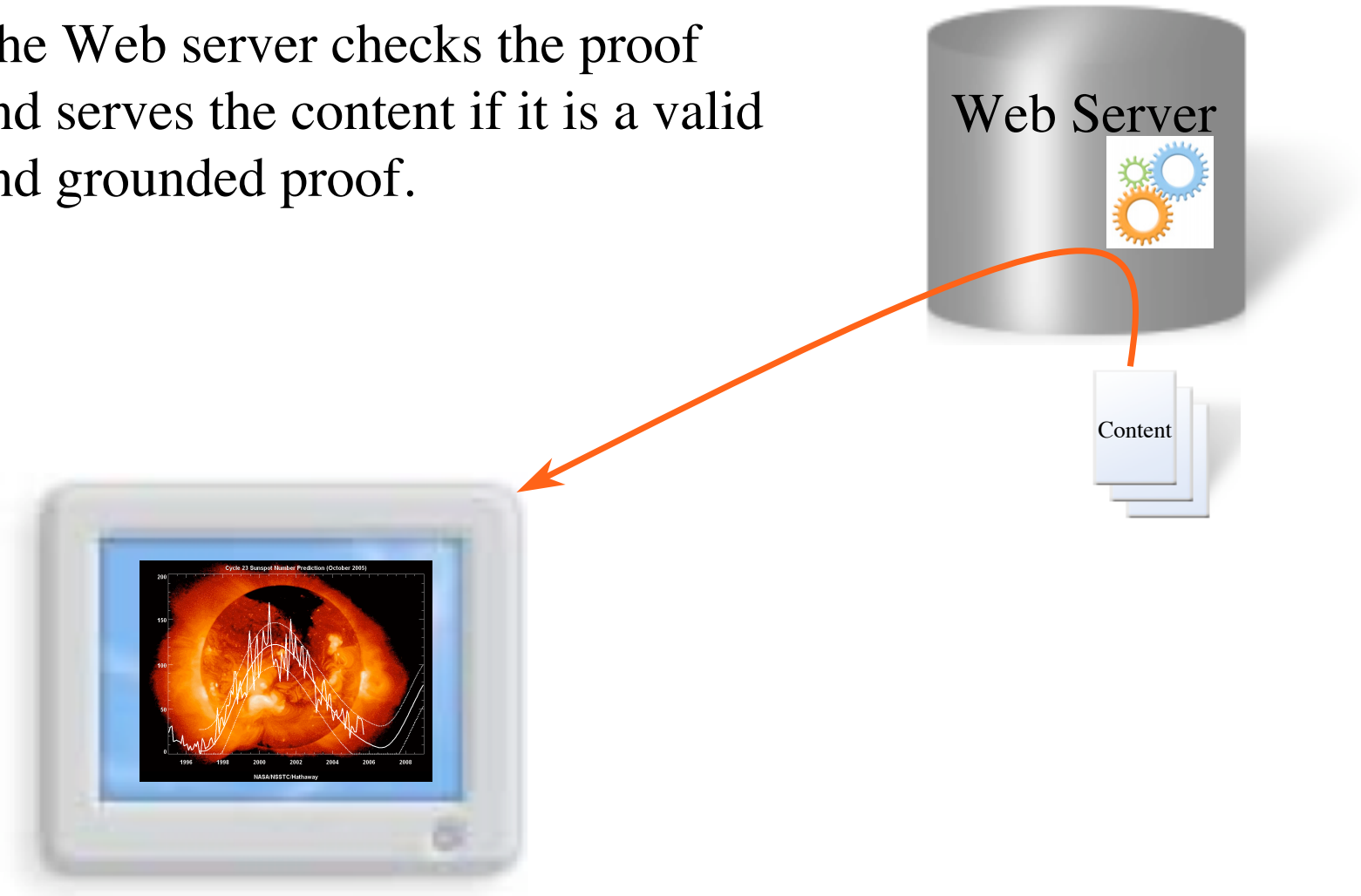
- Cwm
  - Originally developed by Tim Berners-Lee as a forward chaining rules engine for the Semantic Web
  - Based on N3 (formalization in progress)
  - REIN policy engine encoded as cwm rules
  - Cwm extended with proof generator and proof checker

```
{ 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 }.
```

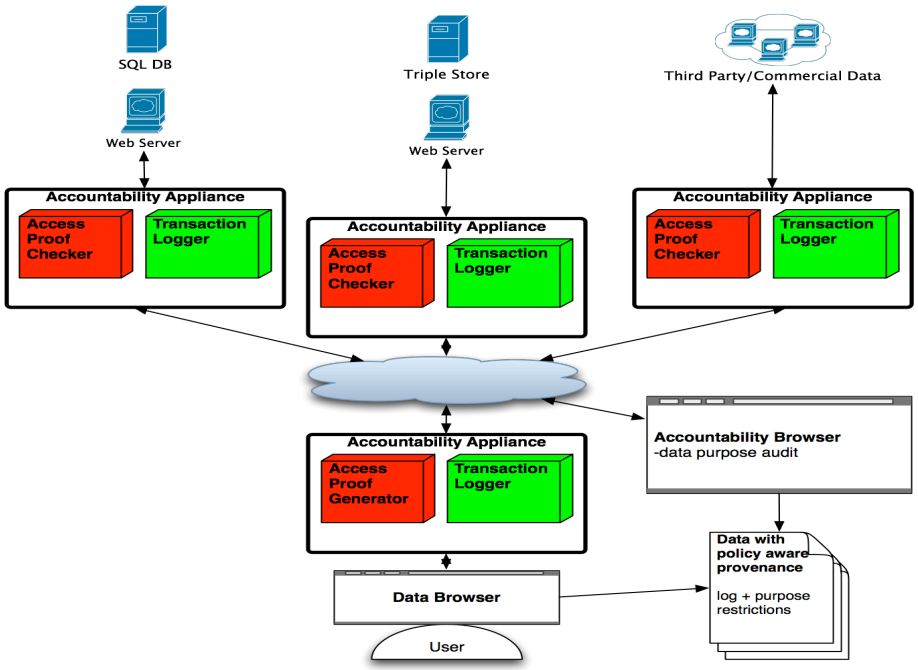
Use of the PAW proof-generation proxy results in a proof which satisfies the policy:



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)

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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???