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)
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

![Diagram](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

```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" >
```
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
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

W3C

- www.semanticweb.org
- www.daml.org
- www.w3.org/RDF/

DAML

- www.semanticweb.org
- www.daml.org

C2 link

Horus

- Ctr for Army Lessons Learned
- US/EU Joint Efforts (S. Decker, Coord)

Research efforts:
- SHOE
- OIL
- EC OntoWeb

Intl Workshops

Tools

Lang Spec

Demos

DAML-ONT

DAML-LOGIC

EU W3C Members/directors (Dan Brickley, coord)
DAML Examples

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

Writing “DAML”!

Using “DAML”!

Reading “DAML”!

Writing “DAML”!

Using “DAML”!

Image: DAML examples diagram showing the process of writing and reading “DAML”.
Query processed:

- A satellite image taken yesterday at 10 AM is available on the web at [http://...](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://...](http://...) for more information
Service Descriptions

CGWeatherService

Display weather-photo

Invocation Description

[Site-Logic]
ReqAuth(site,x) ⇒ Auth(x, CoastGuard)

Procedural Code

External Resource
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"

- User Interface & applications
- Trust
- Proof
- Unifying Logic
- Query: SPARQL
- ontology: OWL
- Rules: RIF
- RDF-S
- Data interchange: RDF
- XML
- URI
- Unicode

Standards: ca. 2006

(Tim Berners-Lee)
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!
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
The linked open data cloud now has billions of assertions, and is growing rapidly.
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)
  - ...
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
Why Mount Eden Vineyard Edna Valley Chardonnay was selected for Fish

### Wine Properties

- **NAME:** Mount Eden Vineyard Edna Valley Chardonnay
- **COLOR:** White
- **BODY:** Medium
- **FLAVOR:** Moderate
- **SUGAR:** Dry

### List of recs being considered

#### Supporting Recs

<table>
<thead>
<tr>
<th>ID</th>
<th>COLOR</th>
<th>BODY</th>
<th>FLAVOR</th>
<th>SUGAR</th>
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<td>Moderate U Strong</td>
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</tr>
<tr>
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<td></td>
<td>Moderate</td>
<td>Dry</td>
</tr>
<tr>
<td>RecDLM Fish</td>
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<td>Medium</td>
<td></td>
<td>Dry</td>
</tr>
<tr>
<td>RecSeafood</td>
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#### Opposing Recs

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<td>Mount Eden Vineyard Edna Valley Chardonnay</td>
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<td>Moderate</td>
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<tr>
<td>RecDLM Scrod</td>
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<td>Delicate</td>
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<tr>
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<td>Sweet</td>
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<td>Delicate</td>
<td>Dry</td>
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<tr>
<td>Rec-2Dhendler</td>
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<td>Light</td>
<td></td>
<td>Dry</td>
</tr>
<tr>
<td>RecDLM Flounder</td>
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<td>Medium</td>
<td>Delicate</td>
<td>Dry</td>
</tr>
<tr>
<td>RecDLM BlandFish</td>
<td>White</td>
<td>Medium</td>
<td>Delicate</td>
<td>Dry</td>
</tr>
</tbody>
</table>
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

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<td>Moderate</td>
<td>Dry</td>
</tr>
<tr>
<td>Rec-2Dhendler</td>
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<td></td>
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</table>

**Opposing Recs**

TOTAL IN CONFLICT: 6

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<tr>
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<tr>
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<td>Moderate</td>
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</tr>
<tr>
<td>RecSeafood</td>
<td>White</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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"

- User Interface & applications
- Trust
- Proof
- Unifying Logic
- Query: SPARQL
- ontology: OWL
- Rules: RIF
- RDF-S
- Data interchange: RDF
- XML
- URI
- Unicode

Standards activities

Research Activities

ca. 2006

(Tim Berners-Lee)
Web Agents need Service Descriptions

Hendler, 2001
Semantic Web Service Description

- `<daml:Class rdf:ID="CreateAcct">
  <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"

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>
</owl:Class>
Semantic Web Services

Advanced information management capabilities
Discovery, Filtering, Composition
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?

You owe me $30

Oh yeah? Prove it

{Purchased(user1,book1,AOL);www.confirm.com#1221122}
{Priceof(book1, $30);AOL-historyDB#29293910}
{Purchase(a,b,c) & Priceof(b,d) -> Owes(a,c,d);www. ont.com/prodont}

The check is in the email!
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)
Use case:
A Web browser requests a page and is given it by a Web server.
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
Content-type: text/html; charset=UTF-8
Connection: close
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:

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)
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???