DAML: ATLAS Project

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CMU: Katia Sycara
Overall Program Summary

- ***What is the basic problem you are trying to solve?***
  - Automatic, runtime Discovery and Interoperation of heterogeneous Web agents that offer services in open, dynamic environments

- ***What was the technical solution strategy?***
  - Exploit and Develop Semantic Web Technologies:
    - Development of language to add semantics to Web Services
    - Develop agents that take advantage of the semantic web

- ***What were the basic elements of the research and program approach?***
  - Leverage Web services technology to define services that agents provide
  - Define a language (OWL-S) for the description of Semantic Web services as an ontology leveraging the Semantic Web languages (OWL+SWRL)
  - Specify algorithms that address all aspects of the development of Semantic Web services: Discovery, Composition, Invocation, Messaging, Monitoring and Verification
  - Develop and disseminate Tools for construction of Semantic Web Services
  - Perform Controlled Evaluation of Semantic Web Services Technology
  - Participate in TIEs and collaborate with other researchers
  - Contribute to standardization efforts (OWL-S, WSA, UDDI, SWSL, SWSA)

CMU: Katia Sycara Technical Problem

- Automatic Interoperation of autonomous agents and the services they provide in an open heterogeneous Web
  - How do agents find potential partners?
  - How do agents work together?
    - How do agents know where to send their messages?
    - How do agents understand each other's message?
    - How do agents compose results of their reasoning?
    - How do agents monitor each other progress to make sure that the ultimate result is reached and the agreements are satisfied?
  - How can ontologies be used effectively to facilitate solution of the above problems?
  - How can industry standards be leveraged?

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- Focus on the services that agents provide:
  - Web services standards provide a way to describe and invoke applications' interfaces on the Web
    - WSDL describes functionalities of Web services and how to invoke them
    - SOAP describes a messaging system used for functionality invocation
  - Autonomous Agents provide functionalities which can be used by other agents or applications
    - Agents' functionalities can be exposed as Web services
- Semantics to Support Web services (Semantic Web Services)
  - WSDL/SOAP describe syntax of messages but no semantics
  - Web services need semantics to make decisions about their operations
- Need Web services infrastructure that is based on Semantic Web
  - Web service descriptions should be based on OWL
  - Web services need
    - semantics for WSDL descriptions
    - descriptions of complete interactions
    - descriptions of capabilities

CMU: Katia Sycara Approach (2)

- OWL-S a language for Semantic Web Services
  - OWL-S is an OWL ontology to describe Web services
    - Describe Web services capabilities
    - Describe Web services Process Model
    - Map Web services Process Model to WSDL for Web service invocation
  - OWL-S allows services to interact on the Semantic Web
    - Description of capabilities allows capability-based discovery of WS
    - Process Model allows construction of plans that compose the activities of different WS
    - Mapping to WSDL allows automatic invocation of WS
  - Adoption Strategy: Complete do not compete
    - OWL-S does not aim to replace the Web services standards rather OWL-S attempts to provide a semantic layer
      - OWL-S relies on WSDL for Web service invocation
      - OWL-S expands UDDI for Web service discovery

CMU: Katia Sycara Approach (3)

- Develop OWL-S Infrastructure for end to end Development of Semantic Web Services
  - Developed discovery matching engine that uses OWL-S Profile
  - Integrated OWL-S matching engine with UDDI registry
  - Developed OWL-S Virtual Machine to provide a general purpose invocation engine for OWL-S Process Model
  - Developed CODE: an end-to-end integrated development environment for OWL-S Web services based on Eclipse
  - Developed OWL-S Broker as a general mediation mechanism
  - Used OWL-S in prototype demonstrations of using HTN planner for automatic invocation and composition of Web services
    - Travel Planner, B2B computer purchasing
- Developed agents that take advantage of the Semantic Web
  - RCal used DAML+OIL to analyze calendars and conference schedules
    - Highlights interesting talks from conference schedules
    - Meeting scheduling reasoning about place and schedule of participants
    - Integrated with MS Outlook

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Technical Progress

- Technical problems
  - Lack of existing work in Web Services, let alone in Semantics for Web Services
  - Lack of understanding of how to use ontologies in agent interoperation
  - When our research started, RDF and OIL (incompatible) were the only Semantic Web technologies
- Metrics and research evaluation
  - Produce a language (OWL-S) that could be used for end to end construction of Semantic Web Services
  - Produce a W3C Note for OWL-S
  - Produce tools with good performance
  - Have tools used by others
  - Influence industry standards
  - Develop a school of thought with international following in theory and applications

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Technical Progress

- *Did you meet your goals?* **YES**
  - OWL-S has been through 6 incremental releases that got user's feedback at each step
  - OWL-S 1.1 has been published as a W3C Note (Nov 22, 2004)
  - CMU has produced many different tools including an IDE for end to end semantic web service development and deployment
  - These tools have been downloaded by hundreds of users
  - Controlled experimentation has shown the CMU OWL-S tools have comparable performance to (non-semantic) industry tools
  - W3C (WSA, WSDL), OASIS (UDDI) used or considered using OWL-S elements
  - OWL-S has been used by many academic, government and industrial researchers for developing applications

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Milestones and Accomplishments (1)

- *Over the course of the time you have been funded by the DAML program, what have you accomplished year-by-year?*
  - **Completed Homework assignments** (yr: 00-01)
  - **Ontologies**
    - OWL-S ontologies and many descriptions of Web services (yr: 00-04)
    - W3C WSA specifications in OWL (yr: 03)
    - US City and State ontologies (yr: 02)
  - **Research and infrastructure**
    - Participated in OWL-S development (yr: 01-04)
    - Development of formal execution semantics for OWL-S (yr: 02)
    - Semantic matching algorithms (yr: 02-04)
    - Algorithms for matching security parameters (yr: 03)
    - OWL-S based mediation (yr 03-04)
    - Extracting ontologies from unstructured text (yr 02-03)
    - Semantic Web technology for bug resolution in open source development (yr 03-04)
    - Verification of correctness of process model specification (yr: 04)
    - Comparative work on OWL-S and WSMO (yr: 04)

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Milestones and Accomplishments (2)

- **Specifications**
  - W3C WSA technical note (yr: 02-03)
  - UDDI Semantic Search (yr: 04)
  - OWL-S Note (yr: 04)
  - Active participation in SWSI (yr: 03-04)
- **Software**
  - OWL-S/UDDI Matchmaker, OWL-S IDE, WSDL2OWL-S, OWL-S VM, OWL-S Broker, OWL-S p2p Discovery, Discovery across COI (yr: 00-04)
- **Community Outreach**
  - Founding member of the Semantic Web Science Association
  - Executive co-chair of the Semantic Web Services Initiative (SWSI)
  - Founding member of the W3C Interest Group on Semantic Web Services
  - Technical Chair of the 2nd International Semantic Web conference
  - Member of numerous PC of conferences and workshops on Semantic Web and Semantic Web Services
- **Papers**
  - 36 peer reviewed papers + 3 currently under review (yr: 01-04)

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Milestones and Accomplishments (3)

- **Panels**
  - WWW04 Panel on “Semantic Web and Web Services: A Marriage Made in Heaven?” (yr: 04)
  - ICWS 04 on “Quality of Service Management in Service Grids and Grid Services” (yr: 04)
- **Tutorials** on Semantic Web services at many conferences
  - AAMAS 02, ISWC02, AAMAS03,ISWC03, AAMAS 04, ICWS04, ISWC04 (yr: 02-04)
- **Keynote Talks** on OWL-S and Semantic Web Services
  - OntoWeb 01, OntoWeb 02, ODBASE 03, CAiSE 03, ICAIL 03, NIST 02, MITRE 03, SETN 04, Agents Day 04 (yr: 01-04)

- *What can you point to of your work in specifications?*

1. Contribution to the **Web services Architecture** (WSA) working group at W3C which resulted in the publication of a W3C Note
2. Specification of an **OWL-based discovery mechanism for UDDI** that has been accepted as a standard by the UDDI Technical Committee
3. Participation in the activities of **SWSI** as head of SWSI and as part of the SWSA architecture committee
4. Participating authors of the **OWL-S W3C** note

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Milestones and Accomplishments (2)

- *What was shown in your various demos?*
  1. **RCal** showed that DAML could be used to improve the functionality of COTS such as Microsoft Outlook
  2. **Travel Planner and B2B computer purchasing** showed how HTN planning could be used in conjunction with an early version of OWL-S (with Toshiba)
  3. **DAMLzon** showed that DAML-S (OWL-S) can be used to interact with existing Web commercial services, specifically the Amazon Web service
  4. **OWL-S/UDDI Matchmaker** showed how OWL-S can be integrated with UDDI and that OWL/OWL-S contribute to a better discovery mechanism in UDDI
  5. Participated in the **SONAT TIE** with BBN and others
  6. **Secure UDDI**: a UDDI that takes into account security parameters
  7. **OWL-S Broker** showed how OWL-S can be used in a fundamental mediation component such as the Broker
  8. **CODE: OWL-S IDE** provides an integrated development environment for Semantic Web services
  9. **Matchmaking across COI boundaries** shows that OWL and OWL-S provide a natural mechanism for a topic-distributed UDDI (with LM)
  10. **Peer to Peer Matchmaking** showed how OWL-S can be used in a P2P network based on the Gnutella protocol (with Sony)

CMU: Katia Sycara Transition/Handoff

- *Where are the results of your work available?*
  - **Did you influence specs?**
    - W3C WSA technical note
    - UDDI Semantic Search
    - W3C OWL-S Note
  - **Did you build software?**
    - OWL-S/UDDI Matchmaker, OWL-S IDE, WSDL2OWL-S, OWL-S Broker, OWL-S VM available on SemWebCentral (http://projects.semwebcentral.org/projects/owl-s-ide)
  - **Did you write papers?**
    - 36 papers in peer reviewed journals, book chapters, conferences, and workshops

    http://www-2.cs.cmu.edu/~softagents/publications
  - **Did you contribute to a commercial company?**
    - A version of the CMU matchmaker is running as part of the **NTT** UDDI UBR
    - CMU discovery algorithm has been used by **IBM** as part of extended UDDI
    - OWL-S has been used by many companies (**IBM**, **SAP**, **Toshiba**, **Fujitsu**)
    - Katia Sycara on Scientific Advisory board of **Caboodle** (startup) and **France Telecom**
  - **How did you change the world? Who is using what you developed?**
    - OWL-S Matchmaker, WSDL2OWL-S are widely used and OWL-S IDE has been released and already downloaded by numerous users
    - Standard Specifications are (and will be) used
    - A whole field of research in academia and industry on Semantic Web Services has been started

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Remaining Issues

Issue	Remediation
	Integration of planning and discovery in Web service composition
	Semantic matching using OWL-S preconditions and effects
	Hardening of OWL-S IDE
	Additional experimental evaluation of the performance of our tools
	Integrating OWL-S with the RETSINA multi agent infrastructure
	Failure handling and compensation model for OWL-S
	Management and Monitoring for OWL-S

CMU: Katia Sycara Summary

- *What is the take-away message from your program?*
  To develop technology to put the A (for agent) into DAML

- Approach
  - We have developed technology to enable the current Web to become machine understandable (Semantic Web)
  - We have developed technology to enable applications/services to be semantically interoperable (Semantic Web Services)
  - We have developed technology so that the Web would be geared towards goal directed applications that intelligibly and adaptively coordinate information and action (Internet filled with context-aware and self organizing agents)

- Outputs
  - OWL-S language to add semantics to Web Services
  - Computational infrastructure to allow end to end development of Semantic Web Services
  - Dynamic discovery and composition algorithms to allow goal directed and flexible behavior of services, thus enabling them to exhibit agent-like behavior