



DAML: ATLAS Project

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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)



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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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Approach



- 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



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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



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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



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)



– **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)



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



- *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)



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- *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



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- *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