AI Planning for Grid/Web Services
Composition, Policy Analysis & Workflow

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IHMC, Pensacola, FL
I-X/KAoS Composer (& Enactor)

Collection of Available Semantic Web Processes/Services

Goals

I-Plan (Planning Service)

Partial Plan

OWL-S

Partial Plan Amended with Policy Related Commentary

KAoS Policy Service

Policies Constraining Usage of Services

Consult Policies

Enactment (e.g. via I-P²)

Enforcement (e.g. via KAoS)

Final Plan

Select

Final Plan
Previous Relevant AIAI Work

- **O-Plan**
  - On-line web service exposing API via CGI scripts since 1994
  - HTTP interface since 1997
  - Simple - single user single-shot plan generator
  - Mixed-initiative – multiple options, multiple users with multiple roles, long transactions, collaborative planning, execution and plan repair on failure
  - Air Campaign Planning Workflow Aid - people and systems

- **I-X**
  - I-X supports the construction of mixed-initiative agents and systems which are intelligible to their users and to other systems and agents
  - Dynamic workflow generation and reactive execution support
  - I-Q query adaptor for OWL, OWL-S lookups via CMU Matchmaker, Semantic Web Queries via OWL and RDQL (AKTive Portal)
  - I-Plan planning/re-planning tool

- **CoAX and CoSAR-TS**
  - Coalition Command and Control/Search and Rescue Task Support
  - Use on CoABS Grid and with KAoS Domain and Policy Services
Previous Relevant IHMC Work

**KAoS**
- Developed domain and policy services compatible with several popular agent (e.g., CoABS Grid, Cougaar, Brahms, SFX) and distributed computing (e.g., CORBA, Grid Computing, Web Services) platforms
- Use of OWL to represent application domain concepts and instances, and policy information
- Analysis and policy disclosure algorithms built on top of Stanford’s Java Theorem Prover

**CoAX and CoSAR-TS**
- Use of KAoS to rapidly specify, deconflict, and enforce policies in coalition agents experiment (CoAX)
- Use of KAoS to define, deconflict, and enforce policies governing access to CMU Semantic Matchmaker information in conjunction with AIAI’s I-X tool set (CoSAR-TS)
FY04 Progress

1. Initial exploration of the research agenda for using AI planners and workflow analysis capabilities as web service composition tools
2. O-Plan Web Service experiments
   - Dealing with Inputs & Outputs
   - Recovering Dataflow from Plan Goal Structure
   - OWL-S Import & Export
3. I-Plan
   - As a web service
   - As a Java planning tool (stand-alone and embedded)
4. KAoS Policy Analysis of workflows
   - Translate instances of OWL-S processes into KAoS Action Classes to allow policies to be written about OWL-S processes
   - KAoS Policy Semantics extended for more sophisticated insertion of policy obligations into OWL-S composite processes
   - KAoS role-value-map extensions allow generation of richer OWL-S dataflow semantics
FY04 Progress

5. Use KAoS Policy Analysis during I-Plan plan generation

6. Scenarios
   - Simple examples – e.g. document handling
   - myGrid biochemistry scenario to identify tool requirements
   - CoSAR scenario - Emerging web Interactive demo of all the integrated technology on CoSAR-TS scenario

Explorations
   - KAoS Workflow Policy Analyzer as a Web Service
   - Link to AKT work on OWL-S manual composition tool (SEdit)
I-Plan Web Service – Search & Rescue

Web service results

O-Plan version 3.3
Release date: 30-Apr-00
Build date: 04-May-00

O-Plan results

Planning statistics
- ram-cycles = 26
- in-alto-remaining = 10
- in-posagens = 0

- TP problem description
- First/last graph of the plan
- Plan statistics
- WWd state when the plan finishes
- Data Flow
- First/last data flow graph

LX Results
- LTP problem description
- Initial plan as XML
- Debugging output
- Final plan as XML
- First/last graph of the plan

Diagram: Search & Rescue Plan Web Service

Diagram: Hospital Selection to Hospital List

Diagram: Hospital Selection Hospital List to Hospital List

Diagram: Hospital Selection Hospital List to Hospital List

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Diagram: Hospital Selection Hospital List to Hospital List

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Diagram: Hospital Selection Hospital List to Hospital List
O-Plan/I-Plan OWL-S Importer

http://ontology.ihmc.us/CoSAR-TS/CoSAR-TS-ServiceOntology.owl
KAoS Policy about an OWL-S Process

Using vocabulary from CoSAR -TS OWL-S Process ontology policies
COSAR-TS Web Interactive Demo

I-Plan Tool – CoSAR-TS Search & Rescue

### Coalition Search and Rescue Coordinator

<table>
<thead>
<tr>
<th>Issues</th>
<th>Description</th>
<th>Annotations</th>
<th>Priority</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</table>

### Coalition Search and Rescue Coordinator

<table>
<thead>
<tr>
<th>Activities</th>
<th>Description</th>
<th>Annotations</th>
<th>Priority</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>example</td>
<td>setup-initial-state</td>
<td>Normal</td>
<td>No Action</td>
<td></td>
</tr>
<tr>
<td>sea-rescue pilot A</td>
<td>red sea 'Gahwad' burns</td>
<td>Normal</td>
<td>No Action</td>
<td></td>
</tr>
<tr>
<td>pick-up-and-transport</td>
<td>pilot A red sea 'Gahwad' burns</td>
<td>Normal</td>
<td>No Action</td>
<td></td>
</tr>
<tr>
<td>US army helicopter</td>
<td>service gahwad at lat-long red sea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sea-injury pilot A</td>
<td>'Gahwad' burns</td>
<td>Normal</td>
<td>No Action</td>
<td></td>
</tr>
<tr>
<td>arabellio-hospital</td>
<td>service pilot A burns to string-0</td>
<td>Normal</td>
<td>No Action</td>
<td></td>
</tr>
</tbody>
</table>

### Coalition Search and Rescue Coordinator

<table>
<thead>
<tr>
<th>State</th>
<th>Pattern</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>longitude Southhampton</td>
<td>-1.404</td>
<td></td>
</tr>
<tr>
<td>maxSpeed USN Michigan</td>
<td>70 km/h</td>
<td></td>
</tr>
<tr>
<td>weapon USS California</td>
<td>biological</td>
<td></td>
</tr>
<tr>
<td>maxSpeed USS California</td>
<td>52 km/h</td>
<td></td>
</tr>
<tr>
<td>maxSpeed GatoMarineHelicopter</td>
<td>120 km/h</td>
<td></td>
</tr>
<tr>
<td>type red sea</td>
<td>location</td>
<td></td>
</tr>
<tr>
<td>type Heathrow</td>
<td>airport</td>
<td></td>
</tr>
</tbody>
</table>

### Coalition Search and Rescue Coordinator

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I-K-C – CoSAR-TS Search & Rescue

### Coalition Search and Rescue Coordinator

**Issues**

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<th>Description</th>
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<th>Priority</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setup initial state</td>
<td>Normal</td>
<td>No Action</td>
<td></td>
</tr>
<tr>
<td>Sea-rescue pilot A, red sea burns</td>
<td>Normal</td>
<td>No Action</td>
<td></td>
</tr>
<tr>
<td>Pick-up and transport pilot A, red sea &quot;Oahwad El&quot; burns</td>
<td>Normal</td>
<td>No Action</td>
<td></td>
</tr>
<tr>
<td>US marine helicopter service, gashwah-at-long red sea Arabian to burns</td>
<td>Normal</td>
<td>No Action</td>
<td></td>
</tr>
<tr>
<td>Treat-injury pilot A, &quot;Oahwad El&quot; burns</td>
<td>Normal</td>
<td>No Action</td>
<td></td>
</tr>
<tr>
<td>Arabian-hospital-service pilot A, burns to string-0</td>
<td>Normal</td>
<td>No Action</td>
<td></td>
</tr>
</tbody>
</table>

### State

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitude Southhampton</td>
<td>-1.404</td>
</tr>
<tr>
<td>Max speed USS_Michigan</td>
<td>70Kmph</td>
</tr>
<tr>
<td>Weapon USS_California</td>
<td>&quot;10 loaded torpedo&quot;</td>
</tr>
<tr>
<td>Weapons WMD</td>
<td>Biological</td>
</tr>
<tr>
<td>Max speed USS_California</td>
<td>53Kmph</td>
</tr>
<tr>
<td>Max speed USN_Marine Helicopter</td>
<td>120Kmph</td>
</tr>
</tbody>
</table>

### Annotations

<table>
<thead>
<tr>
<th>Key</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CoSAR</td>
<td>I-K Process Panels</td>
</tr>
</tbody>
</table>
Some Features of the Approach

1. Planning using OWL-S Service Model IOPE Core
2. Can easily extend to accommodate richer temporal, resource and performer constraints
3. Policy analysis feedback during planning
4. Should separate plan-time model from run-time enactment environment
5. Single shot plan service with re-plan facility or richer “mixed-initiative” multiple-options mode
6. Exploring links to a graphical web service editor
7. Exploring seeking web service description information at planning or enactment time
8. Can run as separate services or as embedded tools
Continuing Issues

1. OWL-S input beyond primitives
2. OWL-S output espec. wrt Preconditions/Effects
3. Two way I-X <-> KAoS rich interchange
4. Widen scope of KAoS policy analysis
5. Discrete vs. continuous analysis of workflows
6. Mixed-initiative planning support, GUI
7. Multiple option exploration, GUI
8. Current service environment vs enactment model
9. When to stop planning – how far to commit
10. LOTS of planning power when we need it
**OWL-S Semantics Issues**

- **OWL-S doesn't yet define a way to express preconditions and effects**
  - The intention is to fix this in SWSL

- **It is awkward to express the data-flow in a composite process that invokes the same service more than once**
  - The intention is to fix this in OWL-S 1.1

- **There are partial orders of service invocations and temporal constraints that the OWL-S control structures cannot express**
  - The intention is to fix this in SWSL
OWL-S Workflow Issues

- **Current Process Model ontology is more suited to the purpose of defining internal structure of a single service**
- **Need to attach Profile restrictions to a step of the workflow; used to find a Matchmaker-registered service that meets requirements during enactment**
- **Composite processes are made up of non-unique instances of processes. We have not been able to find a way to add additional information to a particular step, for instance:**
  - Profile restrictions
  - Policy analysis results
OWL-S Deployment Issues

- There doesn't seem to be an authoritative document that precisely defines the OWL-S semantics. Many questions aren't answered by the Technical Overview or by the OWL definitions of the OWL-S ontologies.
- RDF is awkward to use and difficult to read, and OWL-S doesn't yet have an agreed alternative "surface syntax".
- There is currently no OWL-S editor.
- Doing simple things with OWL-S requires lots of software (e.g. Jena2 and all that it requires or the OWL-S API which requires Jena2 and more).
Continuing Work

- Complete integration of I-Plan Planner with KAoS policy analysis services
  - Also allow the use of WSDL workflow analyses
- Java Web Start version of KPAT to obviate the need for prior installation on user’s machine
- Generic KAoS enforcer for OWL-S
- Mixed-initiative planning, integration with AKT project graphical composition tool
- Web-based demonstration integrating I-Plan, I-P², CMU Matchmaker, KAoS and servlets simulating services
AIAI Summary Report

● **2003 Goal**
  – Link I-X coordination and task support with KAoS agent, domain and policy services
  – Demonstrate in a Search & Rescue scenario in TTCP Binni C2 Domain
  – To be shown as AAAI-2004 Intelligent Systems Demonstrator
    http://www.aiai.ed.ac.uk/project/cosar-ts/demo/isd/

● **2004 Goal**
  – Create a web service composition tool based on AI planning technology that can account for execution policy issues, requirements and constraints

● **Release Plans**
  – Currently I-X version 3.3 and CoSAR demonstration are available via web for research use
  – Open source I-X version 4.0 for research and US government use planned for September 2004. Tool based on this put on SemWebCentral soon after.

● **Plans to end of Project**
  – Do our best to package the results (effort mostly used to date)
  – Do our best to continue to participate in SWSL and W3C SWS-IG
IHMC Summary Report

- **2003 Goal**
  - Provide KAoS domain and policy services to I-X
  - Different from and complementary to CMU Matchmaker Policies and OWL-S security extensions
  - Develop policies and enforcers for Search & Rescue scenario in TTCP Binni C2 Domain

- **2004 Goal**
  - Provide policy analysis capability for OWL-S composite processes (next: WMSO)

- **Release Plans**
  - Web hosting of KAoS and CoSAR demonstrations for research use
  - Distribution of KAoS on SemWebCentral for research and US government use planned for October 2004

- **Plans to end of Project**
  - Enrich policy analyses of OWL-S specified workflow
  - Finish the live Web demonstration of integrated technology and CoSAR scenario by August 2004
  - Collaborate with CMU on Matchmaker improvements and usage
  - Develop generic policy enforcer for OWL-S services
Further Information

- [http://www.aiai.ed.ac.uk/project/cosar-ts/](http://www.aiai.ed.ac.uk/project/cosar-ts/)
- [http://ontology.ihmc.us/](http://ontology.ihmc.us/)
- [http://i-x.info](http://i-x.info)