
Coalition Search and Rescue - Task Support
Intelligent Task Achieving Agents on the Semantic Web

Final Report

Austin Tate & Jeff Dalton
AIAl, Informatics, University of Edinburgh

Jeff Bradshaw & Andrzej Uszok
IHMC, Pensacola, FL



Artificial Intelligence Applications Institute, University of Edinburgh, UK
Institute for Human and Machine Cognition, Pensacola, Florida



Project Summery

- **To provide capabilities linking:**
 - models of organizational structures, policies, and doctrines
 - with intelligent task support software
- **The project integrates:**
 - AIAI's I-X planning and collaboration technology
 - IHMC's KAoS policy and domain services
 - Semantic Web Services of various kinds
- **Search and rescue operations - rapid dynamic composition of available policy-constrained services - good use case for Semantic Web**
- **Other participants in the application include: BBN Technologies, SPAWAR, AFRL, and CMU**



Project Goals

- **Development of base technologies:**
 - I-X/I-Plan
 - KAoS Policy and Domain Services,
- **Deployment of the technology in a realistic CoAX agents demonstrator scenario,**
- **Integration of these two technologies with a perspective of a uniform tool release in the future.**

Project Yearly Outline

- **Year 1: Distributed multi-agent systems were developed and integrated with the semantic web in a realistic coalition search and rescue scenario:**
 - AAI-2004 Intelligent Systems Demonstrator for CoSAR-TS
- **Year 2: An initial web services composition and policy analysis tool for semantic web services (I-K-C) was implemented:**
 - IEEE Intelligent Systems journal article and an ISWC 2004 conference paper



Details of developed technology



Artificial Intelligence Applications Institute, University of Edinburgh, UK
Institute for Human and Machine Cognition, Pensacola, Florida



I-X Technology

- Reasoning about and exchanging with other agents and services any combination of Issues, Activities, Constraints and Annotations
 - represented in the <I-N-C-A> ontology.
- Collaborative task support and exchange of structured messages related to plans, activity and the results of such activity.
- Information can be exchanged with other tools via OWL, RDF or other languages.
- The system includes an AI planner

I-X Process Panel and Tools for a Coalition Search and Rescue Task

Map Tool

Process Panel

Domain Editor

Messenger

I-Space

The screenshot displays the 'Coalition Search and Rescue Coordinator' software. The 'Process Panel' shows a table of issues and activities. The 'Map Tool' shows a map of the Red Sea region with a search area highlighted. The 'Domain Editor' shows a list of activities. The 'Messenger' shows a transcript of messages and a 'Compose Message' section. The 'I-Space' panel shows a list of agents and their relationships.

Issues	Description	Annotations	Priority	Action
	are country and sar-resource...		Normal	No Action

Activities	Description	Annotations	Priority	Action
	rescue F15-Pilot sea bums 18.0 40.0		High	Expand usi...
	select-hospital bums [1: ?hospital="Gahwad EF"] [...]		High	Expand usi...
	lookup-hospitals	Finished -- 7 hospitals cons...	High	Invoke hos...
	select (hospital [1: ?hospital="Gahwad EF"]) (m...		High	Match worl...
	select-sar-resource sea [2: ?country="Arabello"] [...]		High	Expand usi...
	lookup-sar-resources sea "Arabello"		High	No Action
	select (sar-resource [3: ?sar-resource])		High	Done
	notify SAR-Mission-001 [3: ?sar-resource] [3: ?sar...		High	N/A
	notify SAR-Mission-001 [3: ?sar-resource] [1: ?ho...		High	Invoke resources

State	Pattern	Value
	longitude ArabelloCoastguardCutter	38.55
	maxSpeed ArabelloCoastguardCutter	35Kmph
	type ArabelloCoastguardCutter	cutter
	altitude Bandar_Airport	10
	latitude Bandar_Airport	14.02

Agents	Relationships
Arabello-SAR	Subordinate
Australia-SAR	Subordinate
Binni-CFC	Superior
CMUNotifier@jabber.org/Home	Service
Gao-SAR	Subordinate
UK-SAR	Subordinate
US-SAR	Subordinate
hospitals	Service
resources	Service



I-X Process Panels

- **Intelligent ‘to-do’ list for its user**
- **In conjunction with other users’ panels, it can become a workflow,**
 - reporting and messaging ‘catch all’
 - allowing the coordination of activity
- **Presentation of the current items of each of the four sets of entities comprising the <I-N-C-A> model**
- **Can take requests to:**
 - Handle an issue
 - Perform an activity
 - Add a constraint
 - Note an annotation

Policies and Semantic Web Services

- **Semantic Web Services to be used by people but also by software agents**
- **Policy ensure that human-imposed constraints on agents interactions are respected**
- **Policy-based controls can also be used to govern interaction with traditional (non-agent) clients**
- **Proposals for SOAP-based message security and XML-based languages for access control (e.g., XACML2) have begun to appear recently**
- **However only declarative ontology-based policy semantics can fulfill the SWS requirements**

Use of Ontology in KAoS

- **Descriptions of actors, actions, situations at different levels of abstraction, policies**
- **Possibility to dynamically calculate relations among policies and current situation, as well between policies themselves based on ontological relations of used concepts**
 - **Dynamic extension of the policy framework by specifying platform ontology and linking it with generic KAoS framework ontology**
 - **Extension of the framework itself by adding new ontologically-described components**
 - **See: <http://ontology.ihmc.us/>**

KAoS Policies

- **Main types of supported policies:**
 - Authorization – **Negative and Positive**
 - Obligation – **Negative and Positive**
 - » **Associated with a Trigger Specifying Conditions Activating thisObligation**
- **Policy controls actions**
 - Includes a description of the *action template/class*
 - Constitutes a test for the applicability of the policy
- **Policy posses a priority, which enables it to take precedence above contradicting ones**
 - **Will be replaced by a more general precedence mechanism**
 - » **Encoded in OWL**

Policy Syntax Example

```
<?xml version="1.0" ?>
<!DOCTYPE P1 [
  <!ENTITY policy "http://ontology.ihmc.us/Policy.owl#" >
  <!ENTITY action "http://ontology.ihmc.us/Action.owl#" >
  <!ENTITY domains "http://ontology.ihmc.us/ExamplePolicy/Domains.owl#" >
] >
<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  xmlns:owl="http://www.owl.org/2001/03/owl+oil#"
  xmlns:policy="http://ontology.ihmc.us/Policy.owl#"
>
  <owl:Ontology rdf:about="">
    <owl:versionInfo>$ http://ontology.ihmc.us/ExamplePolicy/ACPI.owl $</owl:versionInfo>
    <owl:imports rdf:resource="http://www.owl.org/2001/03/owl+oil" />
    <owl:imports rdf:resource="http://ontology.ihmc.us/Policy.owl" />
    <owl:imports rdf:resource="http://ontology.ihmc.us/Action.owl" />
    <owl:imports rdf:resource=" http://ontology.ihmc.us/ExamplePolicy/Domains.owl" />
  </owl:Ontology>

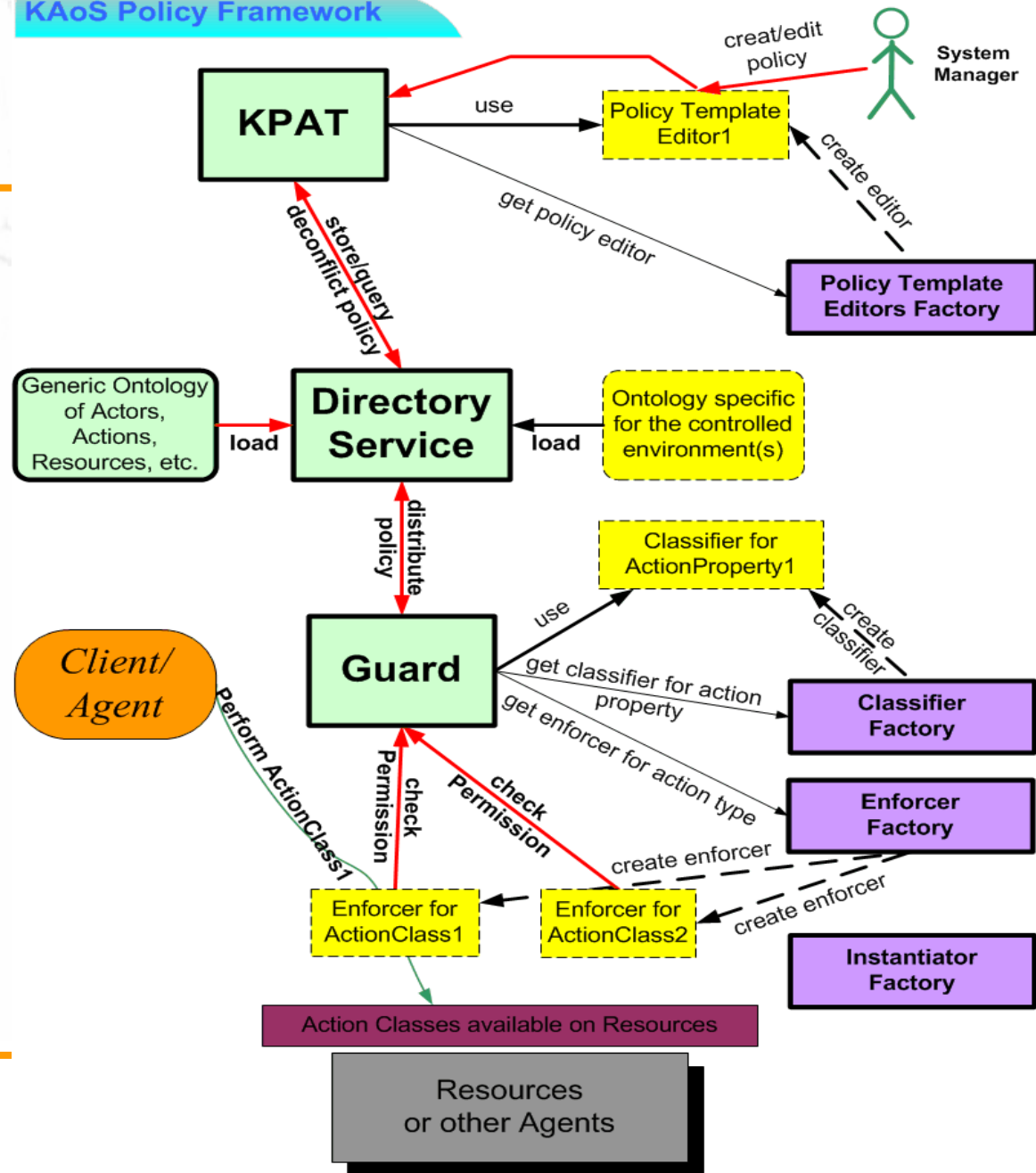
  <owl:Class rdf:ID="OutsiteArabelloCommunicationAction">
    <owl:intersectionOf rdf:parseType="owl:collection">
      <owl:Class rdf:about="&action;NonEncryptedCommunicationAction" />
      <owl:Restriction>
        <owl:onProperty rdf:resource="&action;#performedBy" />
        <owl:toClass rdf:resource="&domains;MembersOfDomainArabello-HQ" />
      </owl:Restriction>
      <owl:Restriction>
        <owl:onProperty rdf:resource="&action;#hasDestination" />
        <owl:toClass rdf:resource="&domains;notMembersOfDomainArabello-HQ" />
      </owl:Restriction>
    </owl:intersectionOf>
  </owl:Class>

  <policy:NegAuthorizationPolicy rdf:ID="ArabelloCommunicationPolicy1">
    <policy:controls rdf:resource="# OutsiteArabelloCommunicationAction " />
    <policy:hasSiteOfEnforcement rdf:resource="&policy;ActorSite" />
    <policy:hasPriority>10</policy:hasPriority>
    <policy:hasUpdateTimeStamp>446744445544</policy:hasUpdateTimeStamp>
  </policy:NegAuthorizationPolicy>
```



Framework Overview

KAoS Policy Framework



Description Logic Reasoning

- **Subsumption-based reasoning used for determination of disjointness:**
 - Finding policy conflicts by determining if two classes of controlled actions classes are disjoint
 - Harmonization of policies
- **Instance classification:**
 - Policy exploration, disclosure, and distribution
- **Usage of Stanford inferencing engine – JTP**

KPAT Hides Complexity

KPAT [- KAoS Policy Administration Tool v2.0

Template Information
Name: Generic DAML Editor
Description: Generic editor for DAML policies

Policy Editor

Policy id: #policy-6ffa1630-00f6-0000-8000-0000deadbeef

Policy name: NotificationAboutMove

Description: This policy obliges any robot to notify some human when it indents moves to a certain location.

Priority: 2

Robot is obligated to perform NotificationAction with properties:

Role	Restriction	Complement	Value(s)
hasDestination	contains at least one	<input type="checkbox"/>	[Human]
hasNotificationMode	is subset of	<input type="checkbox"/>	[Pager, Email]
hasLatency	is subset of	<input type="checkbox"/>	[Immediate]

When Robot performs MobilityAct

hasSeverity

Classes: AdvisorySeverity, CriticalSeverity, LogSeverity, SeverityMode, WarningSeverity

Instances

Commit Refresh

Dynamically obtains list of selections from the ontology repository based on the current context.

Uses **Jena** - Java OWL manipulation library to build policies.

Beyond Description Logic for Policy Representation

- **Originally KAoS used only OWL-DL (initially DAML)**
- **Limited in situations when needed to define policies where one element of an action's context depended on the value of another part of the context:**
 - Example – Loop Communication Action
 - Relation between Trigger Action and Obligated Action
- **These requirements can be fulfilled by role-value-map semantics**
 - maps allow policy to express equality or containment of values that has been reached through two chains of instance properties
- **KAoS was equipped with mechanisms adding role-value-map semantics to defined policy actions when necessary**

Generic Semantic Web Service Policy Enforcer

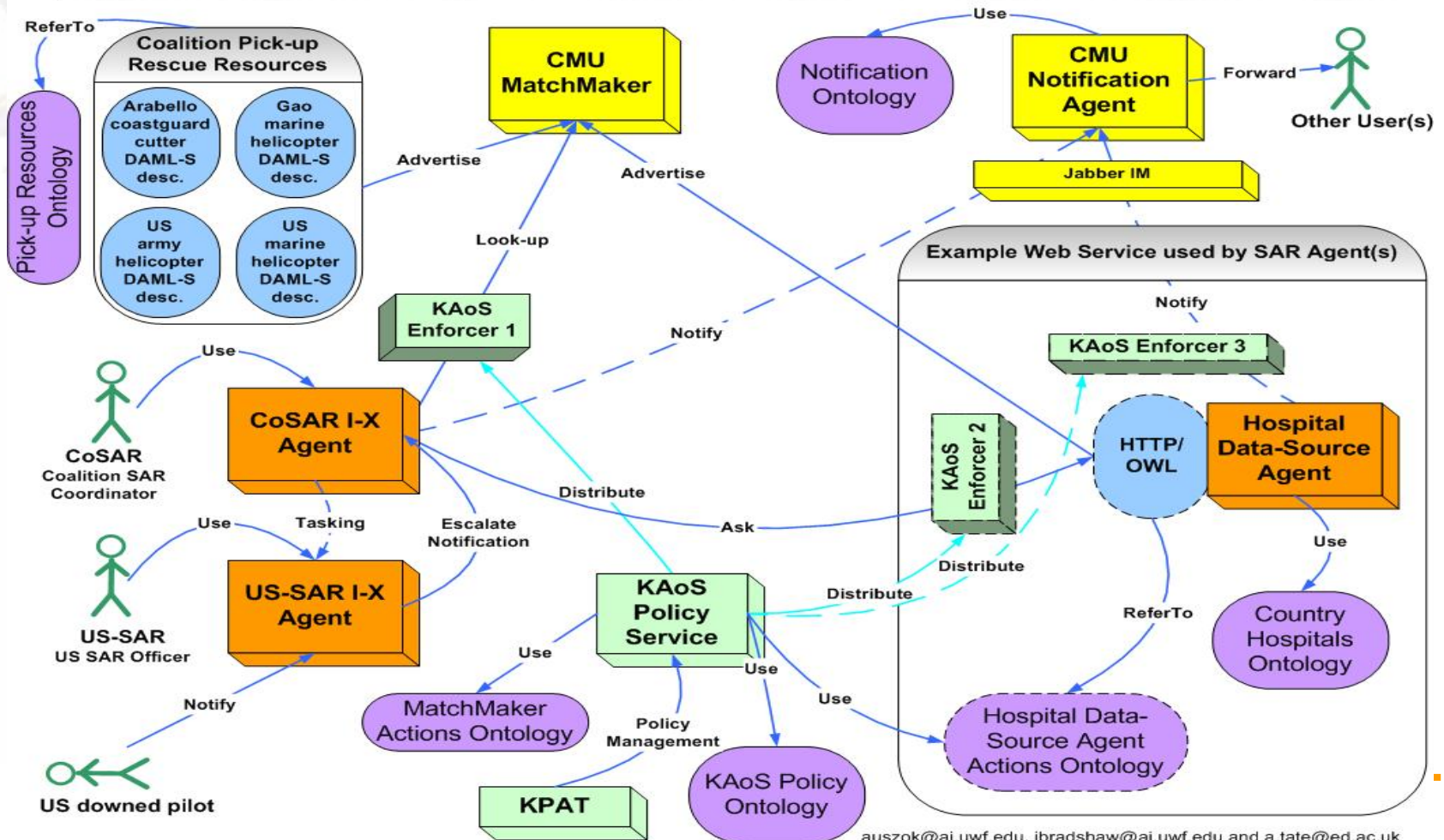
- **Intercept SOAP messages**
- **Understanding arbitrary Semantic Web Service invocations:**
 - Follows annotations from WSDL interface to OWL-S interface
- **Apply appropriate authorization policies to request – filtering these forbidden**
- **It is equipped with a mechanism to perform obligation policies,**
 - which is in a form of other Web Service invocations

CoSAR-TS Scenario

- **Based on the Arabello military scenario from the CoAX (Coalition Agents eXperiment) project**
- **The story begins with an event that reports a downed airman in the Red Sea**
- **Rescue resources (transportation, medical, notification) represented as dynamic Semantic Web Services**
 - Description based on ontology developed for the DARPA SONAT experiment
- **The selection of a SAR resource is made using the CMU Semantic Matchmaker to find a suitable service**
- **These lookups comply with KAoS policies**

CoSAR-TS demo details

CoSAR-TS Demo Concept



auszok@ai.uwf.edu, jbradshaw@ai.uwf.edu and a.tate@ed.ac.uk



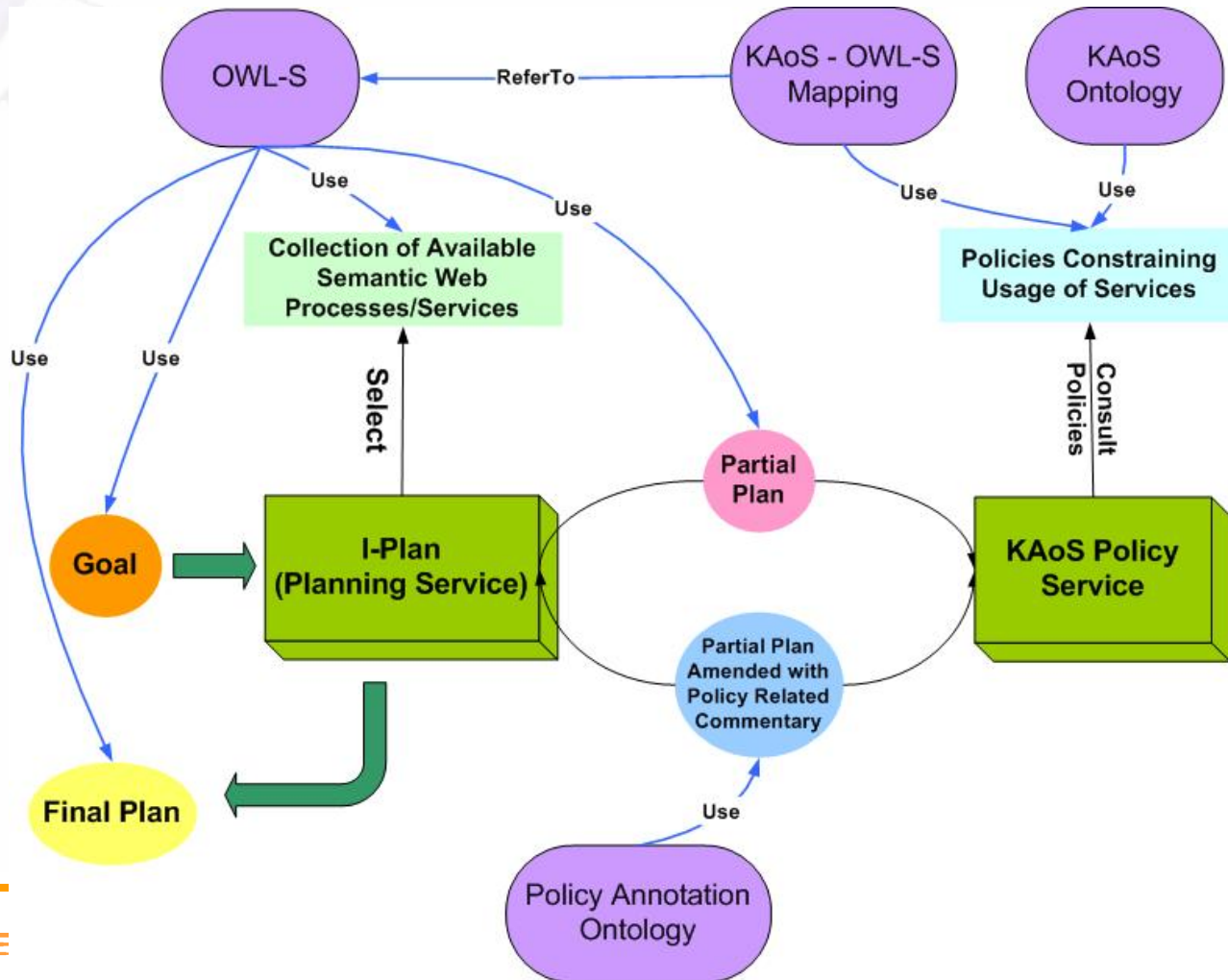
Constraining/Advising Service Workflow Composition



Artificial Intelligence Applications Institute, University of Edinburgh, UK
Institute for Human and Machine Cognition, Pensacola, Florida



I-Plan – KAOs integration



I-X new capabilities

- **Extend the I-Plan planning elements to allow for the creation of composed workflows ahead of execution**
- **Import of services described in OWL-S to be used within the planner**
 - *Dealing with Inputs & Outputs*
 - *Recovering Data flow from Plan Goal Structure*
- ***I-Plan as a web service***

I-Plan Web Service Workflow Composition

The image displays a web browser interface showing the results of an I-Plan web service workflow composition. The browser window is titled "Web service demo results - Microsoft Internet Explorer" and shows the URL `http://today.inf.ed.ac.uk/linux/web-demos/web-service-42-domain.jsp`.

The main content area displays the following information:

- Web service results**
- Planning statistics:**
 - Steps taken = 46
 - Alternatives posted = 41
 - Alternatives picked = 9
 - Alternatives remaining = 32
 - Number of nodes = 8
 - Longest node-end path length = 7
- Alternatives:**
 - am-cy
 - n-alt
 - n-alt
 - n-poi
- TF pr**
- PostS**
- PlanT**
- World**
- Data**
- PostS**
- I-X Result**
 - LTF
 - Initial
 - Debug
 - Final
 - PostS

The browser also displays a "Composition Demo" section with the following text:

The line is a form that lets you specify various parameters. When you submit a problem description which is then submitted to O-Plan or I-Plan.

The "Initial state" section contains the text: `location downed_pilot_1 = sea`.

The browser also displays two "web-service-42-ix-plan-graph[1].ps - GSview" windows showing workflow diagrams. The top diagram shows a sequence of actions: `NODE-0 ACTION (HOSPITAL_LOOKUP TO HOSPITAL_LIST)`, `NODE-1 ACTION (HOSPITAL_SELECTION HOSPITAL_LIST TO HOSPITAL)`, `NODE-2 ACTION (SAR_LOOKUP HOSPITAL TO SAR_RESOURCE_LIST)`, `NODE-3 ACTION (SAR_RESOURCE_SELECTION SAR_RESOURCE_LIST TO SAR_RESOURCE)`, and `NODE-4 ACTION (HOSPITAL_NOTIFICATION HOSPITAL TO)`. The bottom diagram shows a similar sequence of actions: `NODE-0 ACTION (HOSPITAL_LOOKUP TO HOSPITAL_LIST)`, `NODE-1 ACTION (HOSPITAL_SELECTION HOSPITAL_LIST TO HOSPITAL)`, `NODE-2 ACTION (SAR_LOOKUP HOSPITAL TO SAR_RESOURCE_LIST)`, and `NODE-3 ACTION (SAR_RESOURCE_SELECTION SAR_RESOURCE_LIST TO SAR_RESOURCE)`.

Workflow Compositions

- **Incremental plan built by I-Plan defined using combination of processes expressed using OWL-S**
- **KAoS analyzes the proposed plan and annotates it with policy decisions:**
 - **Currently considers individual workflow actions**
 - **In the near future, will take into account action context within the workflow; e.g. actions preceding the given action**

Mapping the OWL-S Process to KAoS Concept Action

- **OWL-S concept of Process maps semantically to the KAoS concept of Action**
- **OWL-S represents Processes as instances, KAoS represents Actions as classes**
- **Need to create an OWL class based on the OWL-S process definition instance**
- **OWL-S API is used to:**
 - load OWL-S process workflows,
 - find all processes within a workflow
 - get detailed definitions about each of them,
- **Using Jena, KAoS builds the OWL class that corresponds to a subclass of the KAoS Action class beign eithr authorize or obliged by policies**

KAoS Workflow Analysis

- **Action class extracted from the workflow is analyzed for policy compliance:**
 - Action authorization and possible additional obligations
- **Using subsumption reasoning KAoS finds relations between the current action class and action classes associated with policies:**
 - deterministic conclusions – when checked action fully subsumes policy action
 - nondeterministic conclusions – when checked action is neither fully subsumed nor fully disjoint with policy action
 - KAoS builds a representation of the new action class by computing the difference between the current action class and the relevant policy action class

I-Plan Java Tool

Coalition Search and Rescue Coordinator

File New Tools Help Test

Issues

Description	Annotations	Priority	Action
are country and sar-resour...		▼ Normal	▼ No Action

Activities

Description	Annotations	Priority	Action
rescue F15-Pilot sea burns 18.0 40.0		▼ High	▼ No Action
select-hospital burns [1:?hospital] [2:?country]		▼ High	▼ No Action
lookup-hospitals		▼ High	▼ Done
load-plan "domain-library/plan-after-full-hospital-loo...		▼ High	▼ No Action
select (hospital [1:?hospital]) (medical-capability [1:?h...		▼ High	▼ No Action
select-sar-resource sea [2:?country] [3:?sar-resource]		▼ High	▼ No Action
lookup-sar-resources sea [2:?country]		▼ High	▼ No Action
select (sar-resource [3:?sar-resource])		▼ High	▼ No Action
notify SAR-Mission-001 [3:?sar-resource] [3:?sar-resour...		▼ High	▼ No Action
notify SAR-Mission-001 [3:?sar-resource] [1:?hospital] F...		▼ High	▼ No Action

State

Pattern	Value
latitude USS_Michigan	16.9
longitude AIAI	-3.186

Annotations

Key	Value

Coalition Search and Rescue Coordinator I-Pla...

File

Planning statistics:
 Steps taken = 5
 Alternatives posted = 0
 Alternatives picked = 0
 Alternatives remaining = 0
 Number of nodes = 10
 Longest node-end path length = 17

Plan Replan Check Plan

Coalition Search and Rescue Coordinator Plan...

File

```

Executing end_of Item[Activity[lookup-sar-resources sea [2:?country]]]
Executing begin_of Item[Activity[select (sar-resource [3:?sar-resource]
Executing end_of Item[Activity[select (sar-resource [3:?sar-resource]
Executing end_of Item[Activity[select-sar-resource sea [2:?country] [3:
Executing begin_of Item[Activity[notify SAR-Mission-001 [3:?sar-resou
Executing end_of Item[Activity[notify SAR-Mission-001 [3:?sar-resour
Executing begin_of Item[Activity[notify SAR-Mission-001 [3:?sar-resou
Executing end_of Item[Activity[notify SAR-Mission-001 [3:?sar-resour
Executing end_of Item[Activity[rescue F15-Pilot sea burns 18.0 40.0]]]
  
```

No problems found.

Cancel

CoSAR I-X Process Panels
Based on I-X Technology

On-line resources

- **CoSAR-TS AAI-2004 Intelligent Systems Demonstrator**
<http://www.aiai.ed.ac.uk/project/cosar-ts/isd/>
- **KAoS KPAT Java Web Start demonstration**
<http://norma.coginst.uwf.edu:8080/coalition/KPAT-TCP.jnlp>
<http://ontology.ihmc.us>
- **I-K-C tool demonstrations**
<http://www.aiai.ed.ac.uk/project/i-k-c>
<http://projects.semwebcentral.org/projects/i-k-c>
- **Web service composition examples**
<http://today.inf.ed.ac.uk/linux/web-demos/web-service-demos/web-service-examples.html>
- **Demonstration on-line web services composer running via a SOAP interface**
<http://today.inf.ed.ac.uk/linux/web-plan/web-plan.html>

Conclusions

- **New sophisticated functionalities in AIAI's intelligent planning technology and IHMC's KAoS services**
 - fully OWL compliant
- **The cooperation between AIAI and IHMC was significantly strengthened**
 - collaborate on future projects
 - release tool integrating both technologies
- **The project deepened understanding of the Semantic Web technology**
 - realistic military scenarios
- **Tested for technologies developed by other DAML program participants**
- **Communication of the value of lessons learned on the project to the OWL and OWL-S committees and forums**