A Reusable Commitment Management Service using Semantic Web Technology

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http://www.csd.abdn.ac.uk/research/akt/cif

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Virtual Organisations

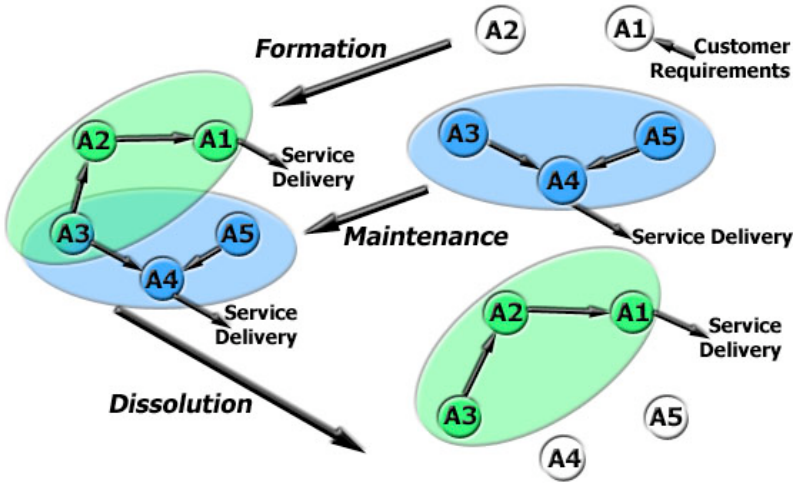

Figure by Tim Norman (AI-2003)

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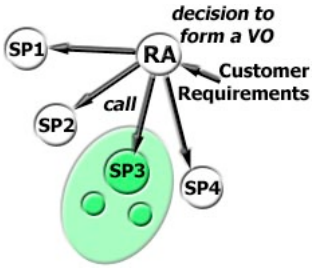
Decision to form a VO



- Package required by customer:
  - Video subscription
  - News digest
  - Music download bundle

- Requester Agent (RA) responds to customer requirements by attempting to form a VO
- Identifies potential suppliers (through yellow pages)
- Issues call for proposals

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Commitment management in virtual organisations (VOs)

- Interesting class of application commonly seen in
  - e-Business
  - e-Science
  - e-Response
- Commitment management throughout the lifecycle of VOs
  - when a partner is bidding to form a VO, its bid must be compatible with its existing commitments
  - when a VO is operating, it must manage its commitments over its collective resources and – when perturbations occur – it must adapt by revising its commitments
  - when a VO's job is done and it disbands, commitments must be released and cleaned-up

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Commitments & constraints

- A service provider manages resources, and commits these to meeting specific goals
  - often commitments governed by SLAs
  - set of commitments C modelled as constraints on resources
- When a SP is presented with a new request R
  - solves the CSP comprising C U R
  - solutions may involve breaking R, or commitments in C
- NOTE: a service-provider can be
  - a single agent acting within an organisation
  - or the VO acting as a collective whole

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Commitments & soft constraints

- Often a CSP is unsolvable: the best we can do is to satisfy a (maximal) subset of the constraints
- Often, not all constraints have to be satisfied for a solution to be valid or acceptable
  - these we call "preferences"
- Constraints often have attached utility values
  - indicate the importance of satisfying individual constraints (or clauses)
  - relative to a particular CSP in which the constraint applies
- We often want to state whether a constraint is satsfied or not in a particular solution context
  - commonly called constraint reification

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Goal

- To create an open, reusable commitment management service (CMS) based on Semantic Web standards
  - reusable in different domains
  - able to manage commitments over services described in a wide range of domain-specific service ontologies
- Why the Semantic Web approach?
  - the majority of service ontologies will be defined in a SW-based representation, currently OWL or RDFS
  - we get all the other Web standards "for free"
    - XML-based interchange formats (inc RDF)
    - transport protocols (HTTP, SOAP, etc)
    - logical foundations (inc DLs, rules)

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CMS requirements

1. An open format for expressing individual commitments as constraints over service descriptions
2. An open format for capturing a set of commitments as a soft constraint satisfaction problem
3. An open format for representing and communicating the solution to a soft CSP
4. A reference implementation of a constraint solver able to operate on (1) and (2) to produce (3)
5. Demonstrations of the CMS working in at least two distinct domains, to provide proof-of-concept of reusability

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Summary of contributions

- Extended version of Constraint Interchange Format (CIF): CIF/SWRL
- Ontology for representing Soft CSPs: CSPO including
  - CSPs and solution sets
  - utility values for constraints
  - constraint reification
- Reusable implementation of a commitment management system - CMS - using the above
  - e-Science application
  - e-Response application

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CMS example 1

- Two agents - `a1` & `a2` - are acting together to provide an amount of resource `x`
  - `a1` has 12`x`
  - `a2` has 10`x`
- The agents have existing commitments on `x`
  - `c1`: 5`x` from time 0→5 on `a1`
  - `c2`: 3`x` from time 6→10 on `a1`
  - `c3`: 5`x` from time 0→7 on `a2`
- New request:
  - `N`: 15`x` from time 0→10
- The agents use a CMS to identify solutions…

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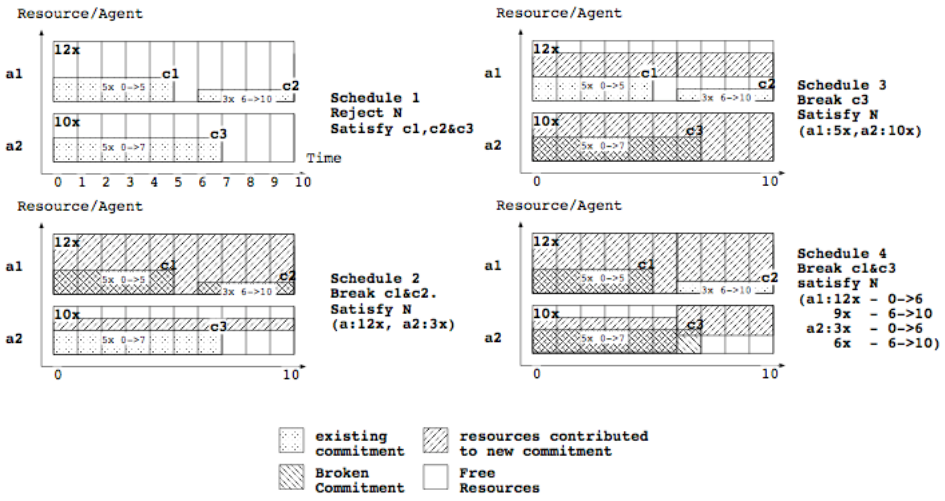
CMS example 2



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CIF & Colan

- Colan (Bassiliades & Gray, *DKE*, 1994)
  - constraint language based on range-restricted FOL
  - used in many domains (bioinformatics, telecoms, Grid…)
  - human-readable syntax, graphical editor available
- Constraints are fully-quantified implications, e.g.

$$(\forall ?x \in X,\ ?y \in Y)\ p(?x,?y) \wedge Q(?x) \Rightarrow (\forall ?z \in Z)\ q(?x,?z) \wedge R(?z) \Rightarrow (\exists ?v \in V)\ s(?y,?v)$$

- Aligned with RDF(S) in 2001 - used to
  - enrich RDF Schemas
  - express integrity constraints on RDF instance data

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CIF/SWRL

- CIF realigned with Semantic Web Rule Language (SWRL) in 2004
  - reuse the SWRL implication syntax
  - add explicit quantification
  - allow nested quantified implications in consequents ("conditional constraints")
- Commitment c2 from the CMS example:

$$(\forall ?t \in \mathrm{Time})\ ?t \geq 6 \wedge ?t \leq 10 \Rightarrow$$
$$(\exists ?c \in \mathrm{Commitment})\ \mathrm{hasService}(?c, ?s) \wedge$$
$$\mathrm{hasServiceType}(?s, \text{'x'}) \wedge \mathrm{hasAmount}(?s, 3)$$

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Requirements for a CSP Ontology

- Collect a set of constraints
- Attach a utility value to each constraint
  - utility values are not intrinsically part of a constraint
  - they are relative to a particular CSP
  - they are a kind of metadata about the constraint
- Associate a set of solutions with the CSP
- State whether a given constraint is satisfied or violated w.r.t. a particular solution

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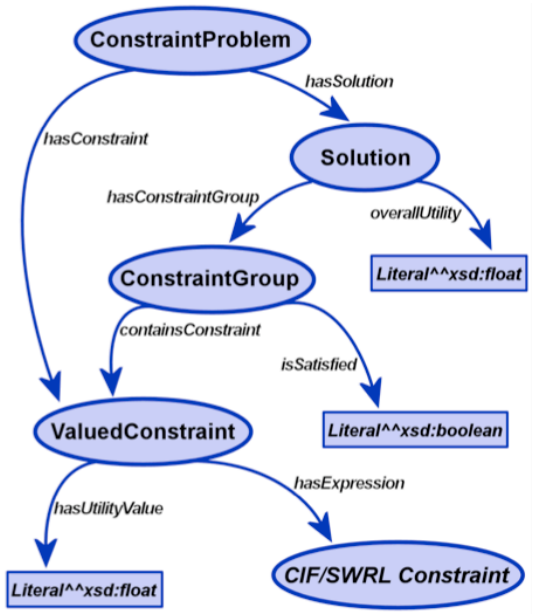
CSPO v1
(OWL DL)



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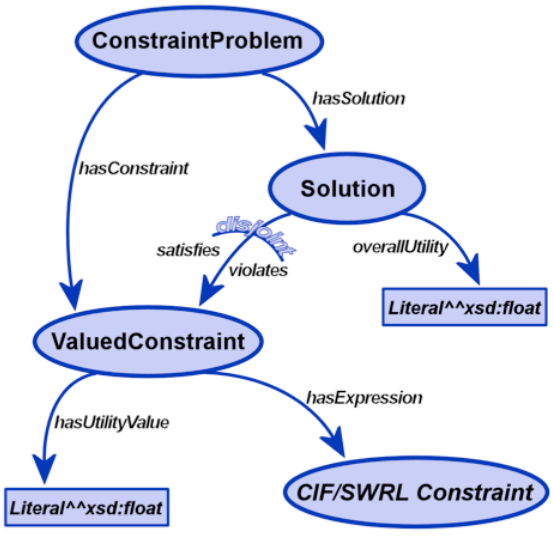
CSPO v2
(OWL DL + SWRL)



SWRL Rule for property disjointedness:
satisfies(?x,?y) & violates(?x,?y) → {empty}.

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Example solution instances

```
<ex:soln1>   <csp:satisfies>   <ex:c1>   .
<ex:soln1>   <csp:satisfies>   <ex:c2>   .
<ex:soln1>   <csp:satisfies>   <ex:c3>   .
<ex:soln1>   <csp:violates>    <ex:N>    .

<ex:soln2>   <csp:violates>    <ex:c1>   .
<ex:soln2>   <csp:violates>    <ex:c2>   .
<ex:soln2>   <csp:satisfies>   <ex:c3>   .
<ex:soln2>   <csp:satisfies>   <ex:N>    .
```

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CIF is an interchange format

1. A user constructs a CSPO instance via a user agent
2. The CSP is shipped to a solver
   - possibly via some intermediary agent(s)
   - possibly with some data gathering beforehand
3. The solver translates/compiles the CSP into its native format, e.g.
   - Java Constraint Library
   - Sicstus Prolog FD Library
   - ECLiPSe
   - CHIP
4. Solutions and reified values are translated back to CSPO to return to the user…

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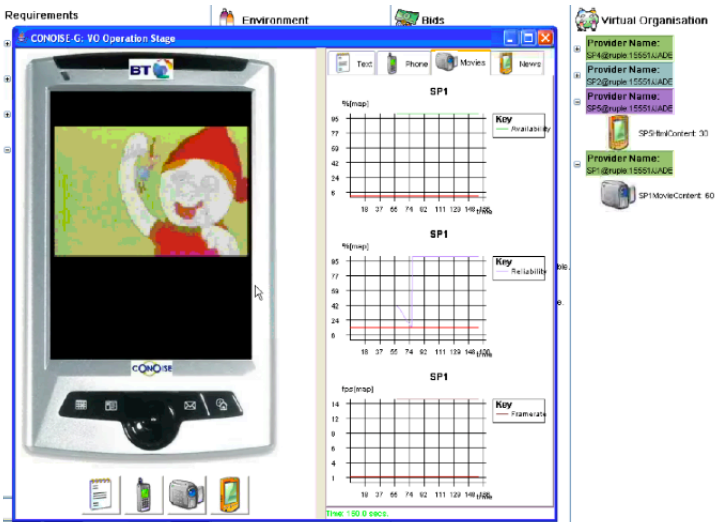
Example app: e-Science



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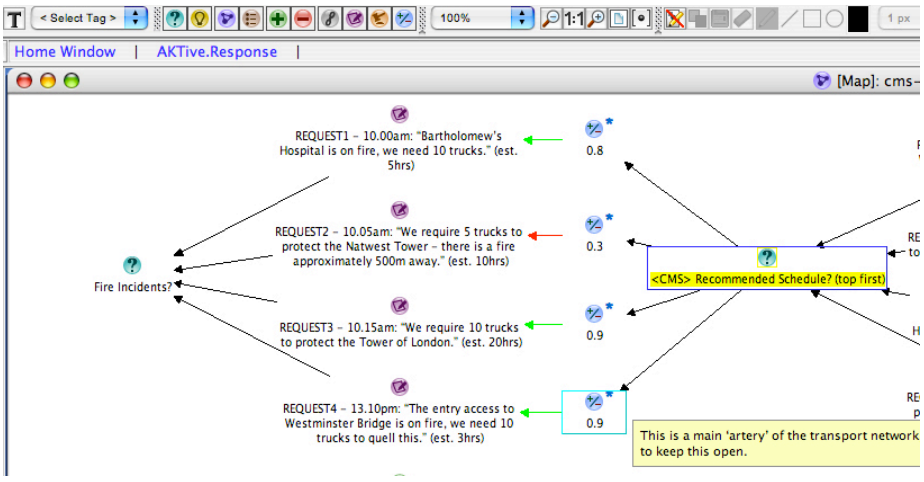
Example app: e-Response



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AKTive.Response - live

Conclusion

- We presented a set of components comprising a reusable CMS for agents operating in VOs
- The components build on the Semantic Web architecture
  - allowing the management of commitments over Semantic Web services
- Some of the components have more general applicability than commitment management:
  - CIF/SWRL and CSPO are reusable for any application of CSP & soft CSP-solving in a SW context
- The first CSP interchange format founded on RDF and OWL

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Future

- While the CSP ontology is designed to work with CIF, it is conceivable that it could incorporate future SW constraint and rule representations (e.g. RIF)
- The SWRL FOL proposal to extend SWRL to full first-order logic shares many of the features we earlier proposed for CIF/SWRL
  - it should be easy to fully align CIF/SWRL with SWRL FOL
- Work on the e-response scenario is ongoing, and our focus is moving onto effective integration of human-mediated and agent-mediated decision processes
  - ITA project: http://www.csd.abdn.ac.uk/research/ita

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Credits & questions?

- This work is supported under the Advanced Knowledge Technologies (AKT) Interdisciplinary Research Collaboration (IRC), which is funded by the UK Engineering and Physical Sciences Research Council (EPSRC) under grant number GR/N15764/01. The AKT IRC comprises the Universities of Aberdeen, Edinburgh, Sheffeld, Southampton, and the Open University. http://www.aktors.org

- The commitment management service was developed in the context of the CONOISE and CONOISE-G projects, involving the Universities of Aberdeen, Cardiff, and Southampton, and British Telecom, and funded by the DTI/Welsh e-Science Centre, and BT. http://www.conoise.org

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