Constraint Logic Programming Applications on the Semantic Web

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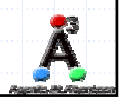
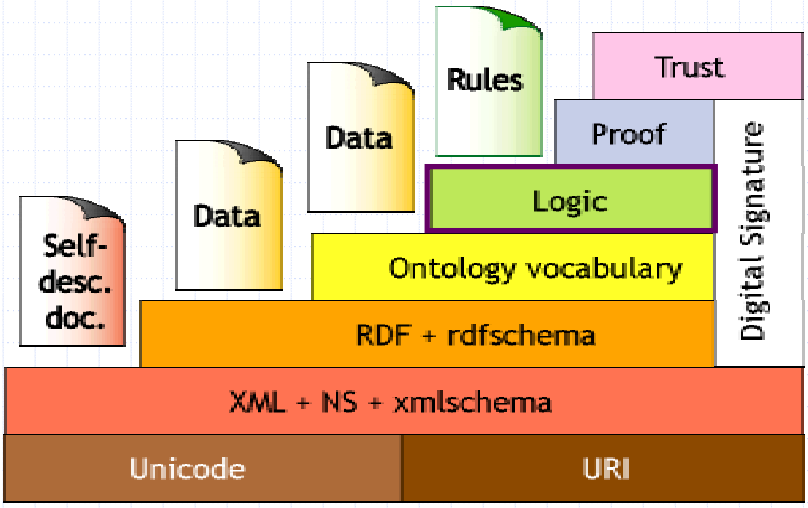
Semantic Web

- Aim: to create a network of machine-processable resources
- Existing in parallel with the current World Wide Web
- Information is marked-up against semantic data models
- Enables software agents to carry out tasks on users' behalf
- Moving from a Web of "finding things" to a Web of "doing things"
- New Semantic Web services will exploit AI techniques



Semantic Web architecture



[Semantic Web 'layer cake' slide due to Tim Berners-Lee]

Problem-solving via CLP

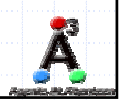
- Many problem-solving tasks can be modelled and enacted as constraint logic programs
  - tasks concerning a single user
    e.g. configuring a product to meet a set of requirement constraints
  - tasks involving multiple users
    e.g. arranging a meeting to satisfy everyone's scheduling constraints
- Such tasks are very relevant in the Semantic Web context
  - offering new services to users by exploiting semantically marked-up information
    e.g. product catalogues, people's schedules

This talk

- Issues
  - representing constraints in a Semantic Web-friendly format
  - interfacing constraint solvers to the open Web environment
- Example applications using CLP to deliver Semantic Web services
  - Planning an evening's entertainment for a visitor to Aberdeen
  - "Infotainment" service-provider coalition formation
  - Supporting design teams

Semantic Web constraint format

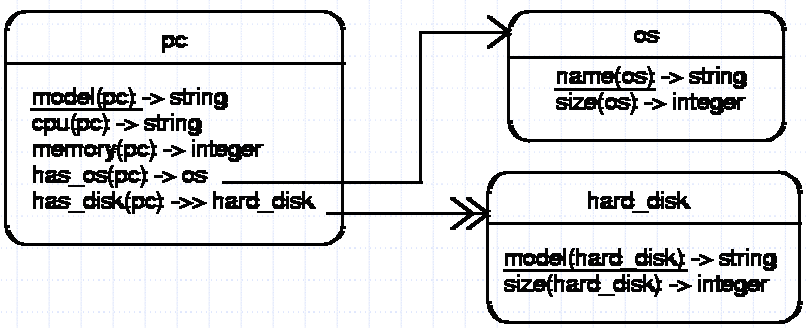
- Serialisable into XML, to make it maximally portable and open
- Constraints should be represented as resources in RDF, so statements can be made about the constraints
- No modification to the existing RDF and RDFS specs, so the CIF would be layered cleanly on top of RDF (and the layers above RDF)
- Possible for constraints to refer explicitly to terms defined in any RDF Schema



XML-CIF

- Modelled using RDF Schema
- Constraints become web resources about which statements can be made (authorship, context, strength, ...)
- Constraints refer to RDFS classes (entities) & properties (relations)
- (We're using RDFS as a lightweight ontology)
- In principle, any RDFS vocabulary can use XML-CIF and our constraint solving services

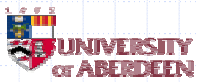
P/FDM schemas



Extended E-R semantic data model

P/FDM to RDFS mapping

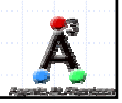
- P/FDM class c declared as c ->> entity maps to an RDF resource of type rdfs:Class
- P/FDM class c declared as c ->> s maps to an RDF resource of type rdfs:Class, with a property rdfs:subClassOf s
- P/FDM function f declared as f(c) -> r maps to an RDF resource of type rdf:Property with rdfs:domain c and rdfs:range r



Colan constraints

```
constrain each p in pc
    to have size(has_os(p))
        =< size(has_disk(p))

constrain each p in pc such that
    manufacturer(p) = "Apple"
    to have name(has_os(p))="MacOS X"
```

This is just syntactically sugared FOL, but it's aimed to be readable to domain experts.

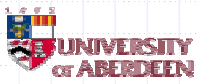


Variables in constraints

- In Colan a variable is always introduced in conjunction with a set that it ranges over.
- Terms such as (p in pc) and (e in employee) are common:

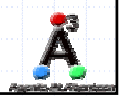
```
(p in pc) such that name (p) = "iMac"
(e in employee) such that
      salary (e) > 5000 and age (e) < 50
```

- Represented by Setmem metaclass
- Variables are described by the Variable class



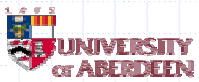
RDFS setmem defn

```
<rdfs:Class rdf:ID="Setmem">
  <rdfs:subClassOf rdf:resource="#Boolprim"/>
</rdfs:Class>

<rdf:Property rdf:ID="var">
  <rdfs:domain rdf:resource="#Setmem"/>
  <rdfs:range rdf:resource="#Variable"/>
</rdf:Property>

<rdf:Property rdf:ID="set">
  <rdfs:domain rdf:resource="#Setmem"/>
  <rdfs:range rdf:resource="#Setexpr"/>
</rdf:Property>
```



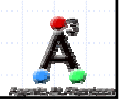
XML-CIF for "(p in pc)"

```
<cif:Setmem>
  <cif:var>
    <cif:Variable rdf:ID="#p"/>
  </cif:var>
  <cif:set>
    <cif:Entset>
      <cif:entclass rdf:resource=
      "http://www.aktors.org/domain/pc_config#pc"
      />
    </cif:Entset>
  </cif:set>
</cif:Setmem>
```



Target applications

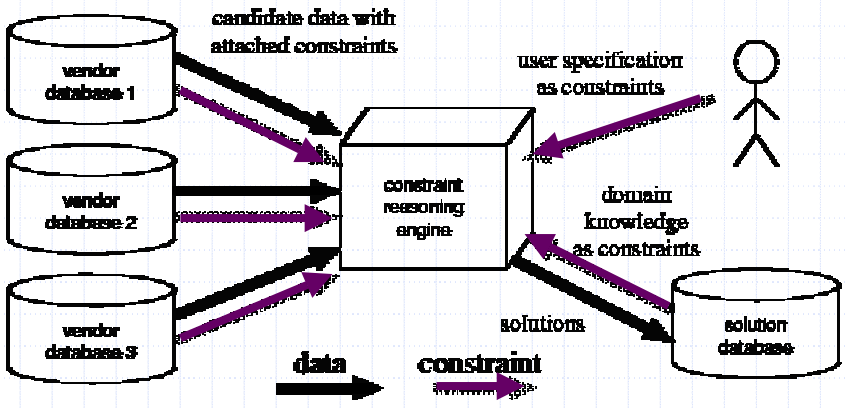
- Supports apps in which info is moved across a network with rich metalevel info on how to use it
- In B2B ecommerce, composition of package products from vendor catalogue components
  - consumer electronic equipment
  - package holidays
  - financial products
- Constraints must be aggregated and solved over available component instances



Fusion of constraints

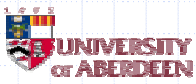
- Customer requirements
  - "I want a PC with a colour printer"
- Constraints on acceptable packages
  - "any printer must have a driver that is compatible with the PC OS"
- Constraints restricting component use
  - "this printer has drivers only for Windows OSes"

Constraint fusion services



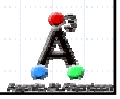
Constraint solver Web services

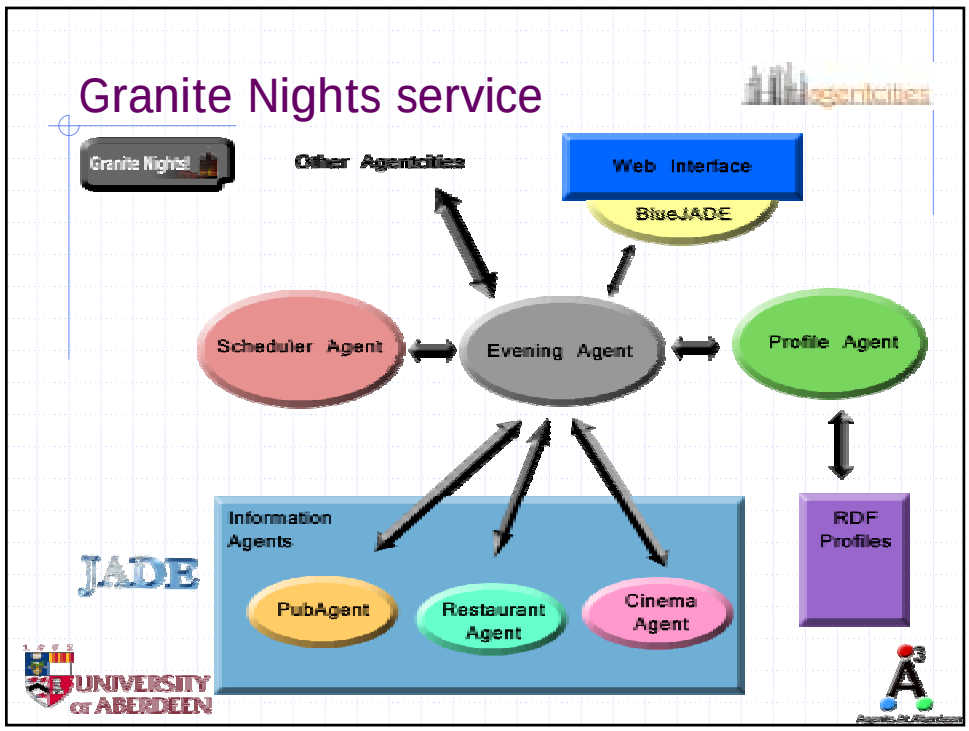
- Wrapping of Sicstus Prolog FD solver as a FIPA-compliant agent
  - Messaging is FIPA ACL over HTTP
  - Content is RDF
  - Platform is JADE+Jasper+Sicstus
- Wrapping of ECLIPSE as an XML-RPC Web service
  - Messaging is SOAP-like AKTbus
  - Content is again RDF
  - Platform is Prolog+Linda+ECLIPSE



Example applications

- Planning an evening's entertainment for a visitor to Aberdeen
- "Infotainment" service-provider coalition formation
- Supporting design teams




Granite Nights service
agenticities
Granite Nights!
Other Agenticities
Web Interface
BlueJADE
Scheduler Agent
Evening Agent
Profile Agent
RDF Profiles
Information Agents
PubAgent
Restaurant Agent
Cinema Agent
JADE
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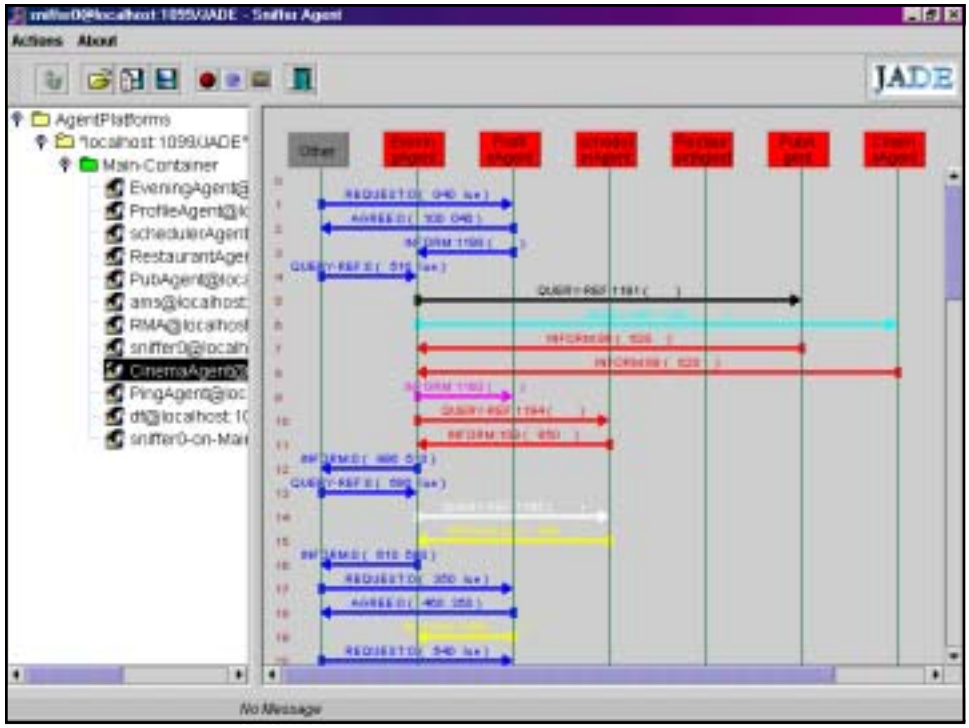
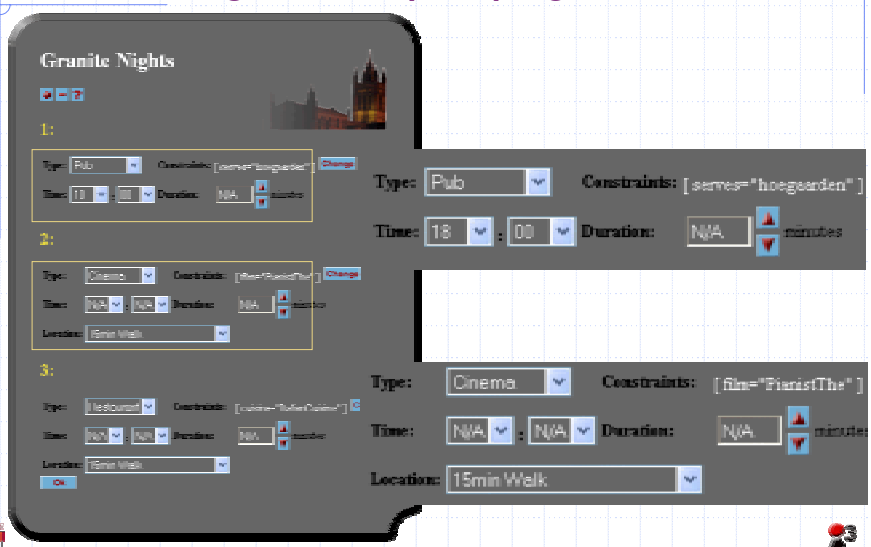
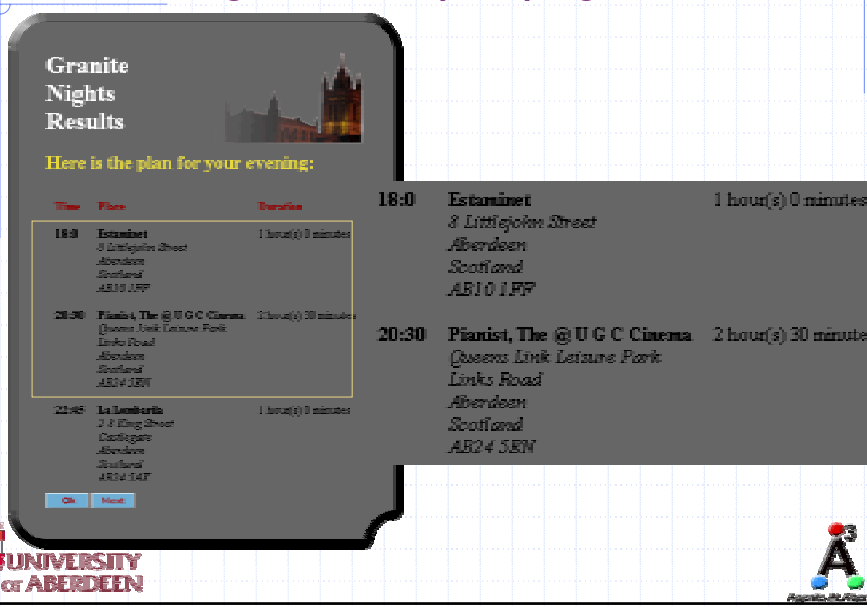

Actions About
JADE
AgentPlatforms
Main-Container
No Message

Granite Nights – input page



Granite Nights – output page



Dynamic info source (cinemas)

Cinema Agent


```
<s:Shows rdf:ID="ugc_PianistThe">
  <s:time>
    <s:ShowScheduleCollection>
      <s:consistsOf><s:ShowSchedule>
        <s:startTime>
          <c:Calendar><c:calendarDate>
           <c:Date>
            <c:dateDayOfWeek
               rdf:resource="cal#Thursday" />
            <c:year>2003</c:year>
            <c:month>1</c:month>
           </c:Date>
          </c:calendarDate><c:calendarTime>
           <c:Time>
             <c:format rdf:resource="cal#24h"/>
             <c:timeHour>20</c:timeHour>
             <c:timeMinute>20</c:timeMinute>
...
  <s:location rdf:resource="cinemas#ugc" />
  <s:description>Certificate: 15</s:description>
  <s:show>
    <s:CinemaPerformance rdf:ID="PianistThe">
    <s:title>Pianist, The</s:title>
```

Static info source (restaurants)

Restaurant Agent

```
<res:Restaurant rdf:about="#lalombarda">
  <res:name>La Lombarda</res:name>
  <res:averageMealDuration>2
    </res:averageMealDuration>
  <res:address>
    <add:Address rdf:about="rest#lombardaaddr"/>
  </res:address>
  <res:atmospheres
   rdf:resource="res#CasualAtmosphere"/>
  <res:atmospheres
   rdf:resource="res#RelaxedAtmosphere"/>
  <res:caterings rdf:resource="res#ALaCarte"/>
  <res:caterings rdf:resource="res#HomeDelivery"/>
  <res:facilities rdf:resource="res#SmokingFacility"/>
  <res:typeOfCuisine
   rdf:resource="res#ItalianCuisine"/>
</res:Restaurant>
```

RDF Query-by-Example

- Principle: query RDF using RDF
- If users can read RDF descriptions, they can write patterns that match RDF descriptions
- Example: "get all pubs serving Guinness beer"

```
<q:Query>
  <q:template>
    <p:EnglishPub>
      <p:servesBeer
          rdf:resource="beertypes#guinness"/>
    </p:EnglishPub>
  </q:template>
</q:Query>
```

More complex queries use CIF expressions

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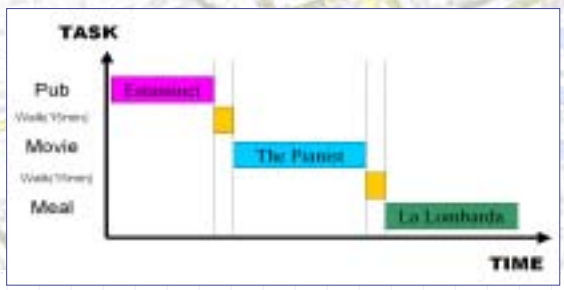
Scheduling agent

Scheduler Agent

- Convert RDF to Prolog representation
- Uses Sicstus Jasper to interface Prolog and Java
- Uses Constraint Logic Programming over finite domains to schedule evening
- Coordinates within map of Aberdeen used for location constraints



CONOISE

SICStus

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RDF to Prolog conversion

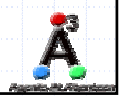
```
<ep:EveningPlan>
  <ep:events>
    <rdf:Seq>
      <rdf:_1>
          <ep:Event>
          <ep:duration>
            <c:Duration>
              <c:durationHour>2</c:durationHour>
              <c:durationMinute>0</c:durationMinute>
            </c:Duration>
          </ep:duration>
          <ep:place>
            <rdf:Alt>
              <rdf:li><pub:EnglishPub rdf:about="pubs#estaminet" /></rdf:li>
              <rdf:li><pub:EnglishPub rdf:about="pubs#wildboar" /></rdf:li>
              <rdf:li><pub:EnglishPub rdf:about="pubs#eastneuk" /></rdf:li>
            </rdf:Alt>
```

```
% data(<name>,<type>,<open>,<close>,<location>).
data('ugc_PianistThe',movie,2020,2248,8,4).
data('lighthouse_PianistThe',movie,1815,2043,7,4).

data('estaminet',pub,1000,2700,7,4).
data('wildboar',pub,1000,2400,6,4).
data('eastneuk',pub,1000,2400,7,5).
```

Example applications

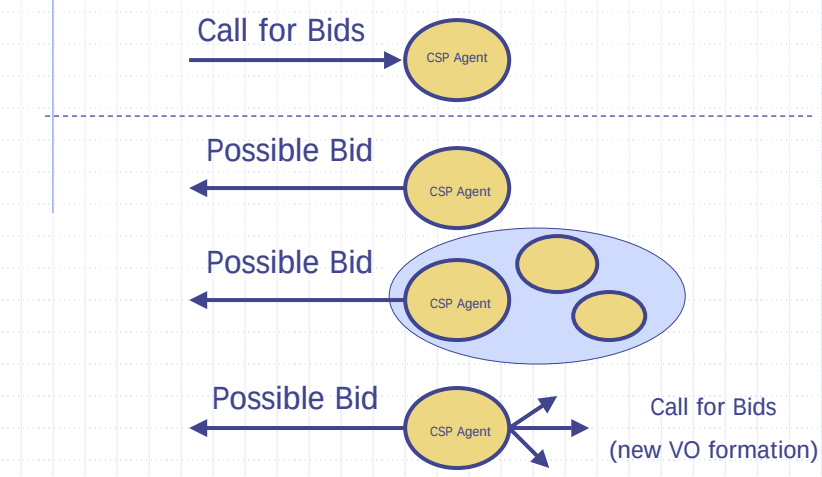
- Planning an evening's entertainment for a visitor to Aberdeen
- "Infotainment" service-provider coalition formation
- Supporting design teams



CONOISE project

- Constraint Oriented Negotiation in Open Information Services Environments
- Multi-site project: Aberdeen, Cardiff, Southampton, BT
- See www.conoise.org
- Automate & investigate Virtual Organisation life-cycle: formation, operation, and disbanding
- CONOISE@Aberdeen: using CLP to decide:
  - who to form VO with
  - when to reform VO
  - when to disband VO

CONOISE interactions



CONOISE: roles of constraints

- Types of constraint
  - user requirements / preferences (hard / soft)
    "monthly package including >= 50 text messages"
  - domain restrictions (axioms on ontology)
    "all Quicktime content requires a Quicktime player"
  - "small print" on instances
    "to get this price, must take the complete package"
  - suppliers' existing commitments
    "40% of my bandwidth is committed to customer X"
- All of these constraints must be factored-in when generating a bid
- Sample bid

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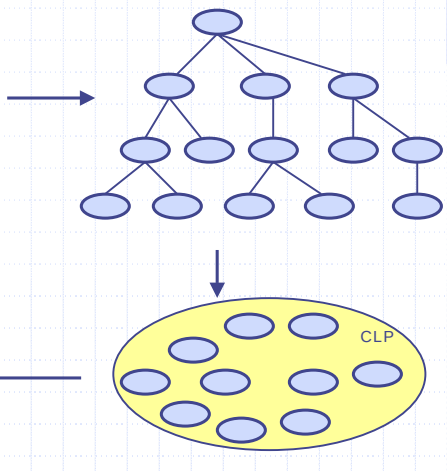
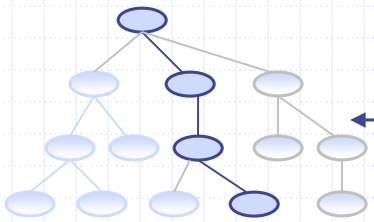
CONOISE: data model & CSPs





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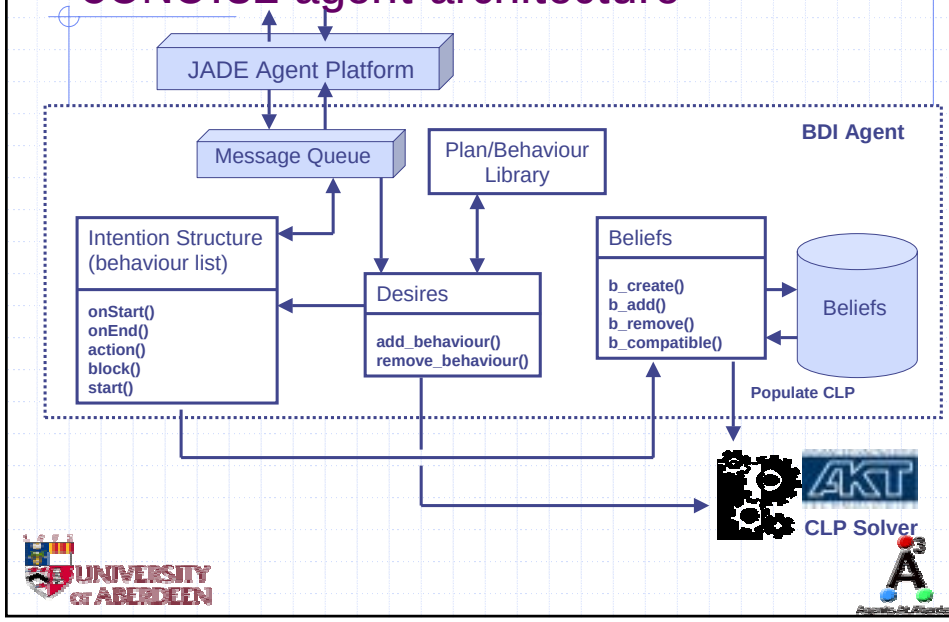
CONOISE agent architecture



Example applications

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- Supporting design teams

I-X/KRAFT service

- Allows people to collaborate on shared tasks
- "Technology integration experiment" (TIE):
  - Edinburgh's I-X provides process panels allowing users to identify & delegate tasks
  - Aberdeen's KRAFT offers constraint solving
- Scenario:
  - Edinburgh user identifies a technical issue, delegates it to Aberdeen
  - Aberdeen resolves issue through constraint solving
  - Example: configuring a PC to user's requirements

Interface (mock-up)

[Demo screencam]

Summary of contributions

- Issues
  - representing constraints in a Semantic Web-friendly format
  - interfacing constraint solvers to the open Web environment
- Example applications using CLP to deliver Semantic Web services
  - Planning an evening's entertainment for a visitor to Aberdeen
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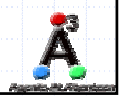
Future work

- Technology
  - clean-up & simplify CIF
  - extend CIF to OWL
  - make solver public on Aberdeen Agentcity node
- Applications
  - CONOISE: VO reformation
  - E-science service composition
  - Constraints as laws; policing open service networks
  - AKT: team-to-team interactions



Credits & Questions?

- Work done at Aberdeen in collaboration with
  - Agentcities: Gunnar Grimnes, Pete Edwards
  - CONOISE: Stuart Chalmers, Tim Norman, Peter Gray
  - AKT: Kit Hui, Peter Gray, Derek Sleeman

Questions?