MARS: Modular Active Rules in the Semantic Web

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Thesis:
There is not a single formalism/language for describing and implementing behavior in the Semantic Web.

Hypothesis:
Semantical approaches (i.e., not “programming”, but based on an ontology of behavior) follow the Event-Condition-Action paradigm.

Justification:
We show that a general framework approach with modular components covers many existing concepts that will prove useful for behavior in the Semantic Web.
Adding Events and Actions to the Ontologies

- Domain languages also describe behavior:

```
<trvl:canceled-flight flight="LH123">
  <trvl:reason>...
</trvl:canceled-flight>
```

```
<trvl:cancel-flight flight="AF456">
  <trvl:reason>...
</trvl:cancel-flight>
```

- Ontology of behavior aspects
- correlate and axiomatize actions, events and state
- combine application-dependent semantics with generic concepts/patterns of behavior
Analysis of Rule Components

“On Event check Condition and then do Action”

Rule Components:

<table>
<thead>
<tr>
<th>Event</th>
<th>Condition</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>dynamic</td>
<td>static</td>
<td>dynamic</td>
</tr>
<tr>
<td>event</td>
<td>query</td>
<td>action</td>
</tr>
<tr>
<td>collect</td>
<td>test</td>
<td>act</td>
</tr>
</tbody>
</table>

- **Event**: detect just the dynamic part of a situation,
- **Query**: then obtain additional information by queries,
- **Test**: then evaluate a *boolean* condition,
- **Action**: then actually do something.

⇒ Modular concepts with Web-wide services
Modular ECA Concept: Rule Ontology

Rule Model

ECARule

EventComponent

ConditionComponent

ActionComponent

Event

State

Action

Ontology

Ontology

Ontology

Event

Language

Query

Test

Action

Language

Languages Model

Language

Name

URI
<!ELEMENT rule (event,query*,test?,action+)>

<eca:Rule rule-specific attributes>
  <eca:Event identification of the language>
    event specification, probably binding variables
  </eca:Event>

  <eca:Query identification of the language>
    <!-- there may be several queries -->
    query specification; using variables, binding others
  </eca:Query>

  <eca:Test identification of the language>
    condition specification, using variables
  </eca:Test>

  <eca:Action identification of the language>
    <!-- there may be several actions -->
    action specification, using variables, probably binding local ones
  </eca:Action>
</eca:Rule>
Embedding of Languages

ECA Language:
<event/> <query/> <test/> <action/>

ECA Language

Active Concepts Ontologies

Domain Ontologies

Event Language

Query Language

Test Language

Action Language

Application-Domain Language

Atomic Events

Literals

Atomic Actions

Composite Events

Queries

Conditions

Complex Reactions
ECA Rule Markup

Ontology of behavior:
- ECA rules
  - (composite) events
  - queries/conditions
  - (composite) actions

Define overall structure

Rules as tree structure **patterns**

Rules, components, expressions as resources

Logical Variables

domain ontology
- atomic events
- atomic actions
- individuals

from domain ontologies extend
Binding and Use of Variables in ECA Rules

\[ action(X_1, \ldots, X_n) ← \]
\[ event(X_1, \ldots, X_k), \ query(X_1, \ldots, X_k, \ldots X_n), \ test(X_1, \ldots, X_n) \]
<!ELEMENT Rule (Event, Query*, Test?, Action+) >
  <eca:Event xmlns:snoop="http://www.snoop.org">
    <snoop:Sequence>
      <travel:delayed-flight flight="{$flight}"/>
      <travel:canceled-flight flight="{$flight}"/>
    </snoop:Sequence>
  </eca:Event>
  <eca:Query bind-to-variable="email">
    <eca:Opaque language="http://www.w3.org/xpath">
      doc("http://xml.lh.de")/flights[code="{$flight}"]/passenger/@e-mail
    </eca:Opaque>
  </eca:Query>
  <eca:Action xmlns:smtp="...">
    <smtp:send-mail to="$email" text="..."/>
  </eca:Action>
</eca:Rule>
Event Expressions: Languages

EventExpression

Atomic Event Description

Composite Event Specification

Domain Event

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Event Detection Communication

users, clients

register ECA rule

ECA Engine

<eca:Rule>
  <eca:Event>
    composite event spec in event algebra CEL
  </eca:Event>
</eca:Rule>

register composite event spec

upon detection:
varbdgs as <log:answers>

Composite Event Detection Service for CEL:
<cel:...> contains
  atomic event spec in formalism AESL
</cel:...>

register atomic event spec

upon matching:
varbdgs as <log:answers>

Event Sources, Domain Brokers

Atomic Event Matcher for formalism AESL
Example as RDF

//local/rules#delay-cancel
eca:Rule

//local/events#delay-cancel
eca:Event

eca:condition

eca:Action

condition

action

travel:delayed-flight

travel:canceled-flight

1

2

travel:AtomicEvent

eca:AtomicEvent

flight

$flight

flight

eca:Event

eca:AtomicEvent

travel:AtomicEvent

eca:AtomicEvent

eca:AtomicEvent

eca:AtomicEvent

eca:AtomicEvent

eca:AtomicEvent
Languages in the Action Component

- Process Engine
- Action Component Language, e.g. CCS
- Composer
  - name
- Event Detector
- Query Engine
- Event Language
- Query/Condition Language
- Domain Broker
- Domain Nodes
- Domain Language
  - uri
- Atomic Events
- Literals
- Atomic Actions

Process Algebra Responsibility

Other Responsibilities

implies
embeds
uses
<eca:Rule xmlns:uni="http://www.education.de">
  <eca:Event> failed twice – binds $student ID and $course </eca:Event>
  <eca:Query> binds e-mail addresses of the student and the lecturer </eca:Query>
  <eca:Action xmlns:ccs="...">
    <ccs:Sequence>
      <ccs:Fixpoint variables="X" index="1" localvars="$date $time $room">
        <ccs:Sequence>
          <ccs:Atomic> send asking mail to lecturer </ccs:Atomic>
          <ccs:Event> answer binds $date and $time </ccs:Event>
          <ccs:Query> any room $room at $date $time available? </ccs:Query>
        </ccs:Sequence>
        <ccs:Alternative>
          <ccs:Test> yes </ccs:Test>
          <ccs:Sequence>
            <ccs:Test> no </ccs:Test>
            <ccs:ContinueFixpoint withVariable="X"/>
          </ccs:Sequence>
        </ccs:Alternative>
        <ccs:Sequence>
          <ccs:Fixpoint>
            <ccs:Atomic> send message ($date, $time, $room) to student </ccs:Atomic>
            <ccs:Atomic> send message ($date, $time, $room) to lecturer </ccs:Atomic>
          </ccs:Sequence>
        </ccs:Fixpoint>
      </ccs:Sequence>
    </ccs:Sequence>
  </eca:Action>
</eca:Rule>
Architecture

1.1: register rule
eca: travel: match: snoop: ccs: smtp:

1.2: register event
travel: match: snoop:

1.3: atomic event patterns
match: travel:

3: detected parameters

2.1a: atomic events
travel:

5.3a: booking
tavel:

2.1b: atomic events
travel:

5.2a: atomic actions
tavel:

5.2b: atomic actions
smtp:

4: detected parameters

5.1: action
ccs: travel: smtp:

Domain Broker
tavel:

Atomic Event Matcher
match:

ECA Engine
eca:

SMTP Mail Service
smtp:

Event Detection
snoop:

Action Engine
ccs:

Lufthansa
tavel:

SNCF
tavel:

Client C:
Travel Agency
tavel:

1.4: register me
tavel:

2.2: atomic events
tavel:

3: detected parameters

1.4: register me
tavel:

5.3b: message (here: confirm) by url

Language Services Application Domain

Application Domain
ECA Architecture

ECA Engine:

```xml
<Rule>
  <Event xmlns:ev="..."/>
  <Query xmlns:ql="..."/>
  <Test xmlns:tst="..."/>
  <Action xmlns:act="..."/>
</Rule>
```

Component Language Services

- travel: LH
- banking: SNCF

Domain Brokers

- uni:
- ...

Domain Services

Generic Request Handler

- component, input var.bdgs
- resulting variable bdgs
Communication of Variable Bindings

Sample XML markup for communication of a query and variable bindings:

```xml
<eca:Query xmlns:ql="url"
  rule="rule-id" component="component-id">
  <!-- query component -->
  <eca:Query>
    <log:variable-bindings>
      <log:tuple>
        <log:variable name="name" ref="URI"/>
        <log:variable name="name"> any value </log:variable>
      </log:tuple>
      ...</log:tuple>
      ...</log:tuple>
    </log:variable-bindings>
  </eca:Query>
</eca:Query>
```
Communication Component Engine → GRH

result-bindings-pairs (semantics of expression)

```
<log:answers rule="rule-id" component="component-id">
  <log:answer>
    <log:result>
      <!-- functional result -->
    </log:result>
    <log:variable-bindings>
      <log:tuple> ... </log:tuple>
      :
      <log:tuple> ... </log:tuple>
    </log:variable-bindings>
  </log:answer>
  <log:answer> ... </log:answer>
  :
  <log:answer> ... </log:answer>
</log:answers>
```