The RuleML Perspective on Deliberation-Reaction Standards

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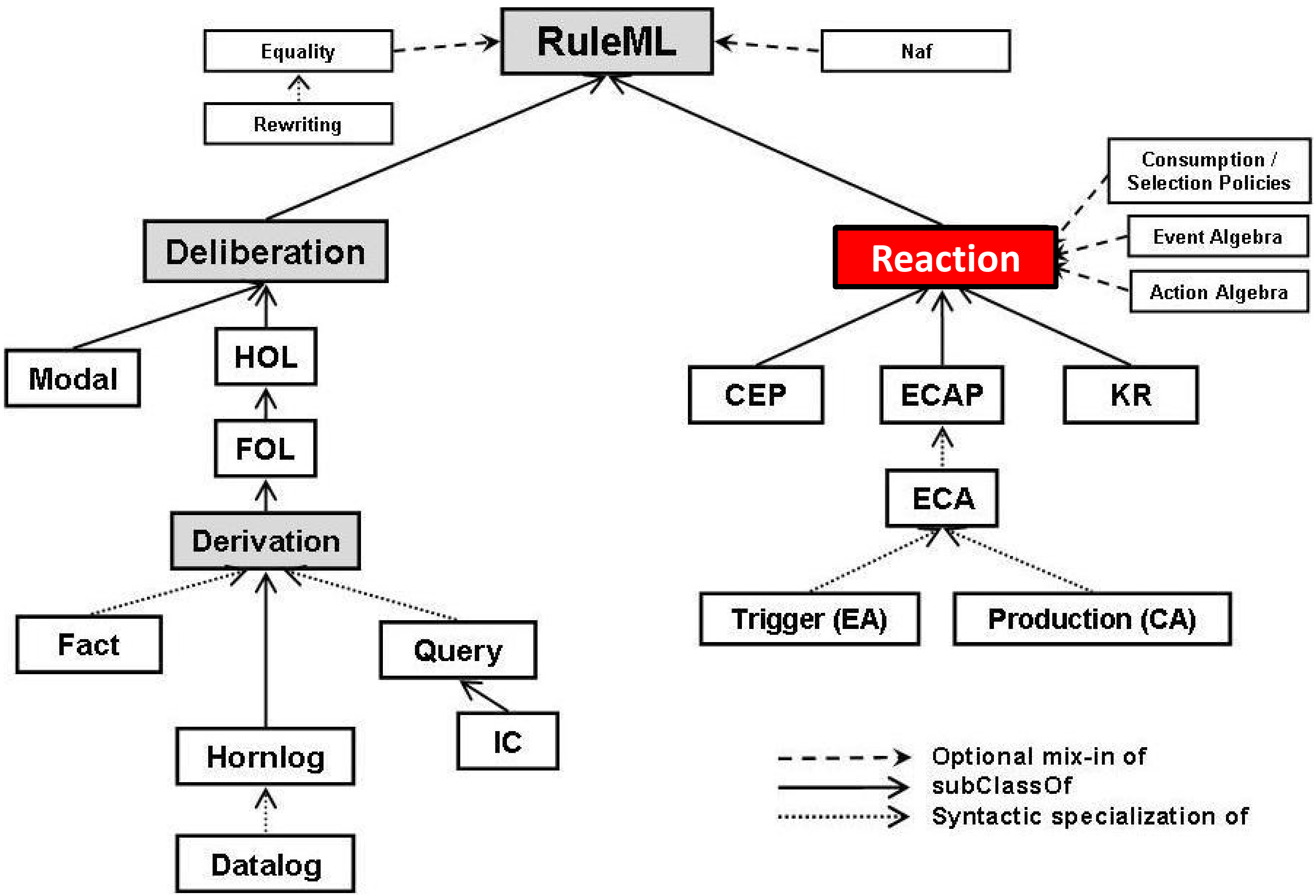
RuleML
Realize your Knowledge

Agenda

- Reaction RuleML
- Semantic Profiles
- Semantic Metamodel and External Ontologies (Semantic Sorts)
- Syntactic Customization

The RuleML Family



Reaction RuleML 1.0 Paper: http://link.springer.com/chapter/10.1007%2F978-3-642-32689-9_9
Reaction RuleML 1.0 Tutorial: http://www.slideshare.net/swadpasc/reaction-ruleml-ruleml2012paschketutorial
RuleML 1.0 Paper http://link.springer.com/chapter/10.1007/978-3-642-16289-3_15
RuleML Overview Slides: http://cs.unb.ca/~boley/talks/RuleML-Overarching-Talk.pdf

Quick Overview: Reaction RuleML Dialects

* + variants and alternatives

- **Spatio-Temporal Derivation RuleML** (*if-then*)*
  - Time, Spatial, Interval
- **KR RuleML** (*if-then* or *on-if-do*) *
  - Situation, Happens$_{(@type)}$, Initiates, Terminates, Holds, fluent
- **Production RuleML** (*if-do*) *
  - Assert, Retract, Update, Action
- **ECA RuleML** (*on-if-do*) *
  - Event, Action, + (event / action algebra operators)
- **CEP** (arbitrary combination of *on, if, do*)
  - Receive, Send, Message

(Reaction) Rules: Specializable Syntax

```
<Rule @key @keyref  @style>
```

Info, Life Cycle Mgt.

```
  <meta>  <!-– descriptive metadata of the rule -->          </meta>
  <scope>  <!–- scope of the rule e.g. a rule module -->    </scope>
```

Interface

```
  <evaluation>   <!-- intended semantics -->                </evaluation>
  <signature> <!– rule signature -->                        </signature>
```

Imple-mentation

```
  <qualification> <!–- e.g. qualifying rule metadata, e.g.
                  priorities, validity, strategy -->        </qualification>
  <quantification>  <!-- quantifying rule declarations,
                   e.g. variable bindings -->               </quantification>
  <oid>  <!– object identifier -->                          </oid>
  <on>     <!–- event part -->                              </on>
  <if>     <!–- condition part -->                          </if>
  <then>   <!-– (logical) conclusion part -->               </then>
  <do>     <!--  action part -->                            </do>
  <after>  <!–- postcondition part after action,
           e.g. to check effects of execution -->           </after>
  <else>  <!–- (logical) else conclusion -->                </else>
  <elsedo>  <!-- alternative/else action,
           e.g. for default handling -->                    </elsedo>
</Rule>
```

Reaction RuleML – Example Rule Types

- **Derivation Rule:**
  (temporal/event/action/
  reasoning)

```
<Rule style="reasoning">
    <if>...</if>
    <then>...</then>
</Rule>
```

- **Production Rule:**

```
<Rule style="active">
          <if>...</if>
          <do>...</do>
</Rule>
```

- **Trigger Rule:**

```
<Rule style="active"> >
          <on>...</on>
          <do>...</do>
</Rule>
```

- **ECA Rule:**

```
<Rule style="active">
          <on>...</on>
          <if>...</if>
          <do>...</do>
</Rule>
```

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Integration of Semantic Profiles

1. **Include/Import external Semantic Profile**

```
<xi:include href="../../profiles/SituationCalculusProfile.rrml" xpointer="xpointer(/RuleML/*)"/>
<evaluation>
  <Profile keyref="&ruleml;ReifiedClassicalSituationCalculus" />
</evaluation>
```

2. **Reference pre-defined Semantic Profile as profile type**

Reference published external semantic profiles, e.g. RIF, OWL, profiles …

```
<evaluation>
  <Profile type="&rif;RDFS“ iri="http://www.w3.org/ns/entailment/RDFS"/>
</evaluation>
```

3. **Locally defined Semantic Profile**

```
<Assert>
  <evaluation>
    <Profile key="&ruleml;ReifiedClassicalSituationCalculus" >
      <formula><Rulebase > ... RuleML  definition… </Rulebase></formula>
      <content>  … xs:any XML content, e.g. RIF, Common Logic XML… </content>
    </Profile>
   </evaluation>
   <Rulebase>
      <Rule> … </Rule>
      <Rule> … </Rule>
   </Rulebase>
</Assert>
```

Note: also other non RuleML content models are supported

Complex Event Processing – Semantic Profiles

(defined in <evaluation> semantic profiles)

1. **Definition**
   - Definition of event/action pattern e.g. by event algebra
   - Based on declarative formalization or procedural implementation
   - Defined over an atomic instant or an interval of time, events/actions, situation, transition etc.
2. **Selection**
   - Defines selection function to select one event from several occurred events (stored in an event instance sequence e.g. in memory, database/KB) of a particular type, e.g. "*first*", "*last*"
   - Crucial for the outcome of a reaction rule, since the events may contain different (context) information, e.g. different message payloads or sensing information
3. **Consumption**
   - Defines which events are consumed after the detection of a complex event
   - An event may contribute to the detection of several complex events, if it is not consumed
   - Distinction in event messaging between "multiple receive" and "single receive"
   - Events which can no longer contribute, e.g. are outdated, should be removed
4. **Execution**
   - Actions might have an internal effect i.e. change the knowledge state leading to state transition from (pre-)condition state to post-condition state
   - The effect might be hypothetical (e.g. a hypothetical state via a computation) or persistent (update of the knowledge base),
   - Actions might have an external side effect

Example - Reaction Rules with Semantic Profiles

```
<Rule style="active">
  <evaluation>
     <Profile> e.g. selection and consumptions policies  </Profile>
  </evaluation>
 <signature>
     <Event key="#ce1">
          … event pattern definition (for event detection)
     </Event>
 </signature>
<on>
 <Event keyref="#ce1"/> <!– use defined event pattern for detecting events -->
</on>
<if>
      …
</if>
 <do>
     <Assert safety="transactional">  <!-- transactional update -->
        <formula>
                 <Atom>
                             ….
                 </Atom>
         </formula>
       </Assert>
  </do>
 </Rule>
```

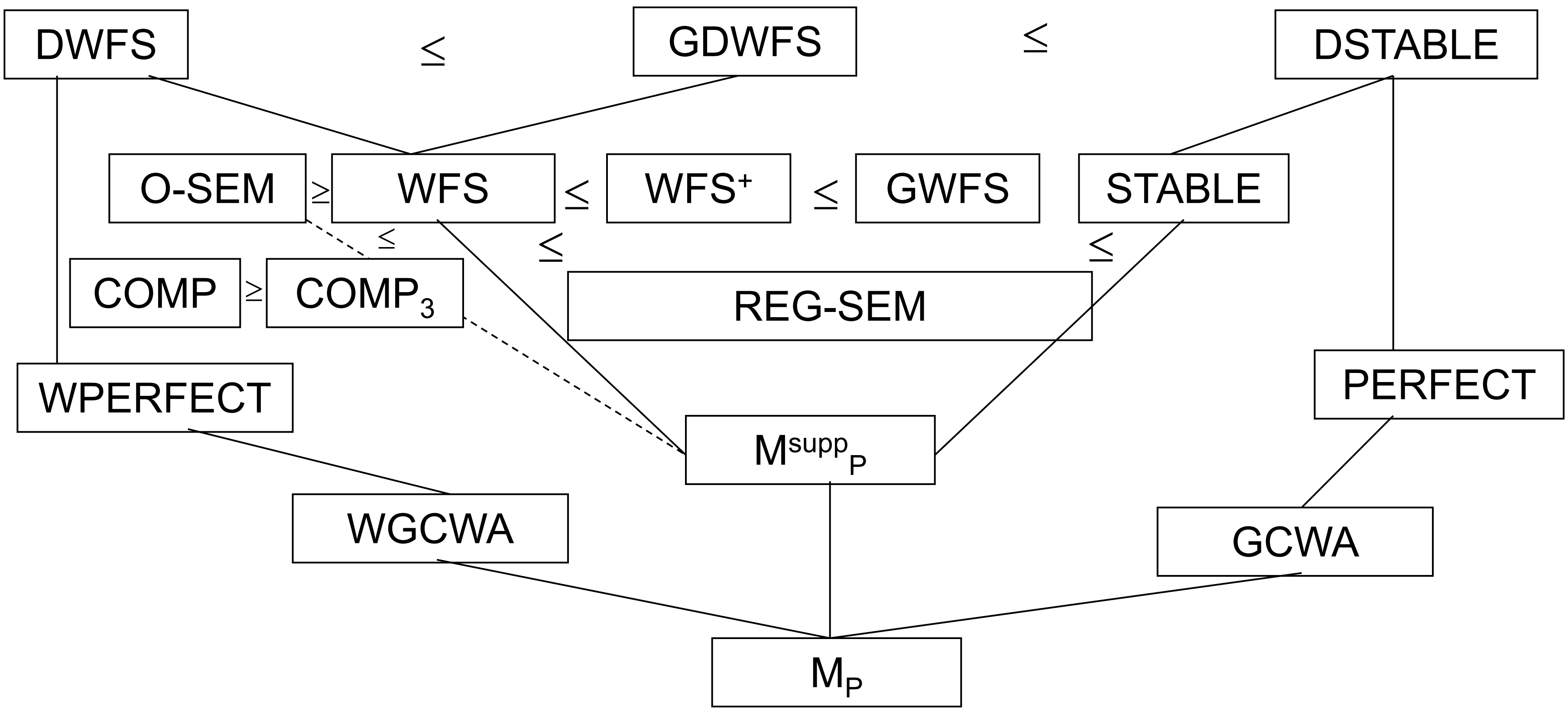
Interface

(semantic profile + event pattern signature for event processing / detection)

Implementation

(reaction rule triggered by event detection)

Semantic Layering - Example LP Semantic Profiles



A semantic SEM‘ extends a semantic SEM:

SEM‘ $\geqslant$ SEM iff $\forall$ (P, F) SEM(P) |= F ➔ SEM‘(P) |= F

Example: Use of Semantic LP Profiles for Interpretation

```
<-- rule interface with two alternative interpretation semantics and a signature.
   The interface references the implementation identified by the corresponding key -->
<Rule key=“#r1">
 <evaluation index="1">
   <!-- WFS semantic profile -->
   <Profile type="&ruleml;Well-Founded-Semantics" />
 </evaluation>
 <evaluation index="2">
  <!-- alternative ASS semantic profile define in the metamodel -->
  <Profile type="&ruleml;Answer-Set-Semantics" />
 </evaluation>
 <!-- the signature  defines the queryable head of the backward-reasoning rule -->
 <signature>
   <Atom><Rel>likes</Rel><Var mode="+"/><Var mode=“-"/></Atom>
 </signature>
</Rule>
```

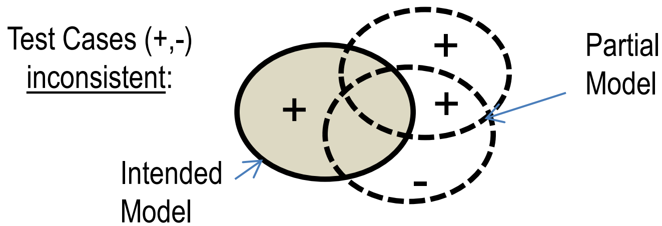
Interface with **evaluation semantics** and public rule **signature**

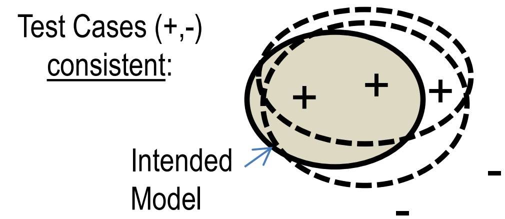
```
<!-- implementation of rule 1 which is interpreted either by WFS or by ASS semantics
     and only allows queries according to it's signature definition. -->
<Rule keyref=“#r1" style="reasoning">
  <if>...  </if>
  <then>
    <Atom><Rel>likes</Rel><Var>X</Var><Var>Y</Var></Atom>
  </then>
</Rule>
```

Implementation

Test Cases for Self-validating Rule Bases

- Test Cases constrain the possible models and **approximate the intended models** of the rule base
  - **Queries** are used to test the rule base





- A test case is defined by T := {X, A, N}, where
  - $X \subseteq L$ assertion base (input data, e.g. facts)
  - $A \in L$ a formula denoting a test query
  - *N := + , –* a positive or negative label
- Semantics

$$\mathrm{M}_0 \models_{\mathrm{TC}} (\mathrm{X}, \mathrm{A}, +) \text{ iff } \forall \mathrm{m} \in \mathrm{M}_0 : \mathrm{m} \in \Sigma(\mathrm{Mod}(\mathrm{X}), \mathrm{R}) \Rightarrow m \in Mod(A)$$

$$\mathrm{M}_0 \models_{\mathrm{TC}} (\mathrm{X}, \mathrm{A}, -) \text{ iff } \exists \mathrm{m} \in \mathrm{M}_0 : \mathrm{m} \in \Sigma(\mathrm{Mod}(\mathrm{X}), \mathrm{R}) \Rightarrow m \notin Mod(A)$$

  - $|=_{TC}$ compatibility relation
  - Mod association function between sets of formulas and sets of models
  - Σ model selection function

$A \notin C_R(X)$ for T:={X, A, +} and $A \in C_R(X)$ for T:={X,A,-}

  - $C_R(X)$ deductive closure of X. Decidable inference operator based on formal proofs

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RuleML Types (Sorted Logic)

- Types (sorts) can be assigned by using the **@type** attribute
- External vocabularies / ontologies define types, e.g.,

  <Var type="&vo;Vehicle">Car</Var>

  <Ind iri="&vo;Corolla" type="&vo;Sedan"/>
- Semantics defined / linked by Semantic Profile, e.g. order-sorted logic using RDFS or OWL entailment profiles

Reaction RuleML Examples with Types from RuleML Metamodel and External Ontologies

<Quantifier type="“&ruleml;Forall"> == <Forall>

<Operator type="&ruleml;And"> == <And>

<Operator type="&ruleml;Conjunction"> == <Conjunction>

<Negation type="&ruleml;InflationaryNegation"> == <Naf>

<Action type="&ruleml;Assert"> == <Assert>

<Action type="&ruleml;Retract"> == <Retract>

<Event type="&ruleml;SimpleEvent"> == <Atom> … </Atom>

<Event type="ibm:CommonBaseEvent"> == IBM CBE

<Operator type="snoop:Squence"> == Snoop Algebra
== <Operator type="&ruleml;Sequence"> == <Sequence>

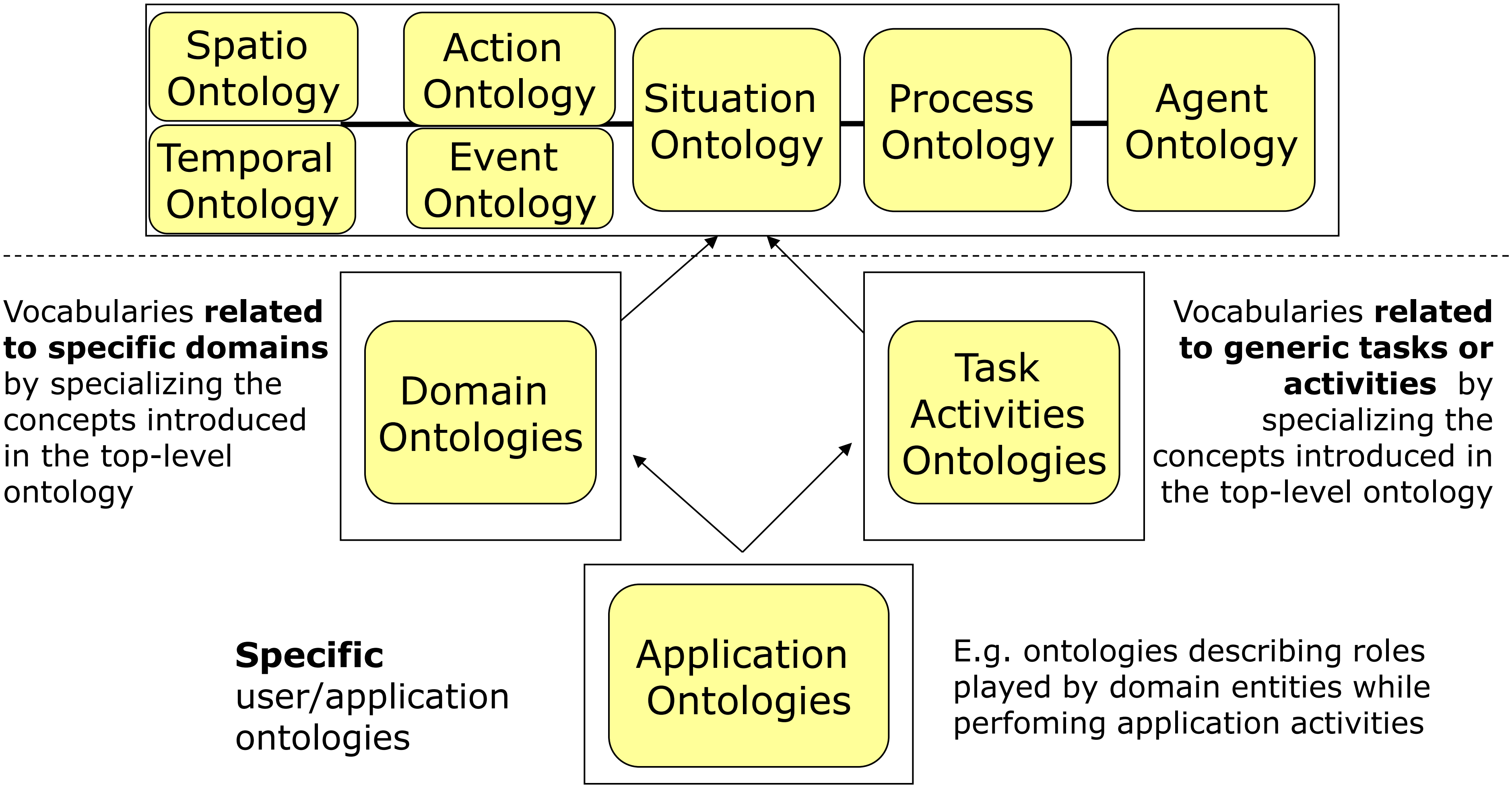
<Ind iri="person.xml#xpointer(//Person/LastName[1]/text())"/>

<Action iri="BPEL.xml#xpointer(//invoke[@name=checkHotel])">

Reaction RuleML Metamodel

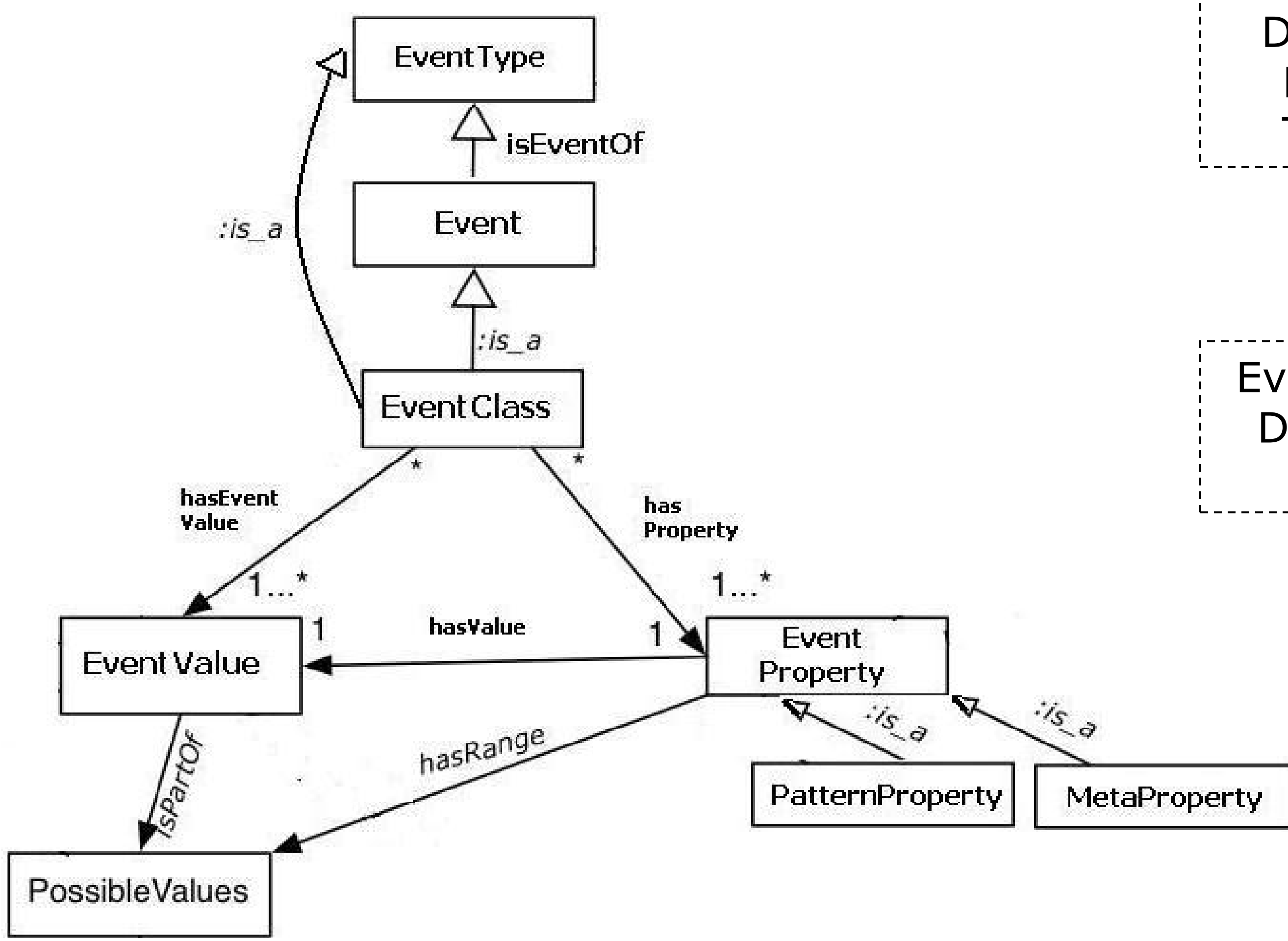
Top Level Ontologies

General concepts such as space, time, event, action and their properties and relations



Example - Event MetaModel

(for defining Event Types as Instances of the MetaModel Event Class)

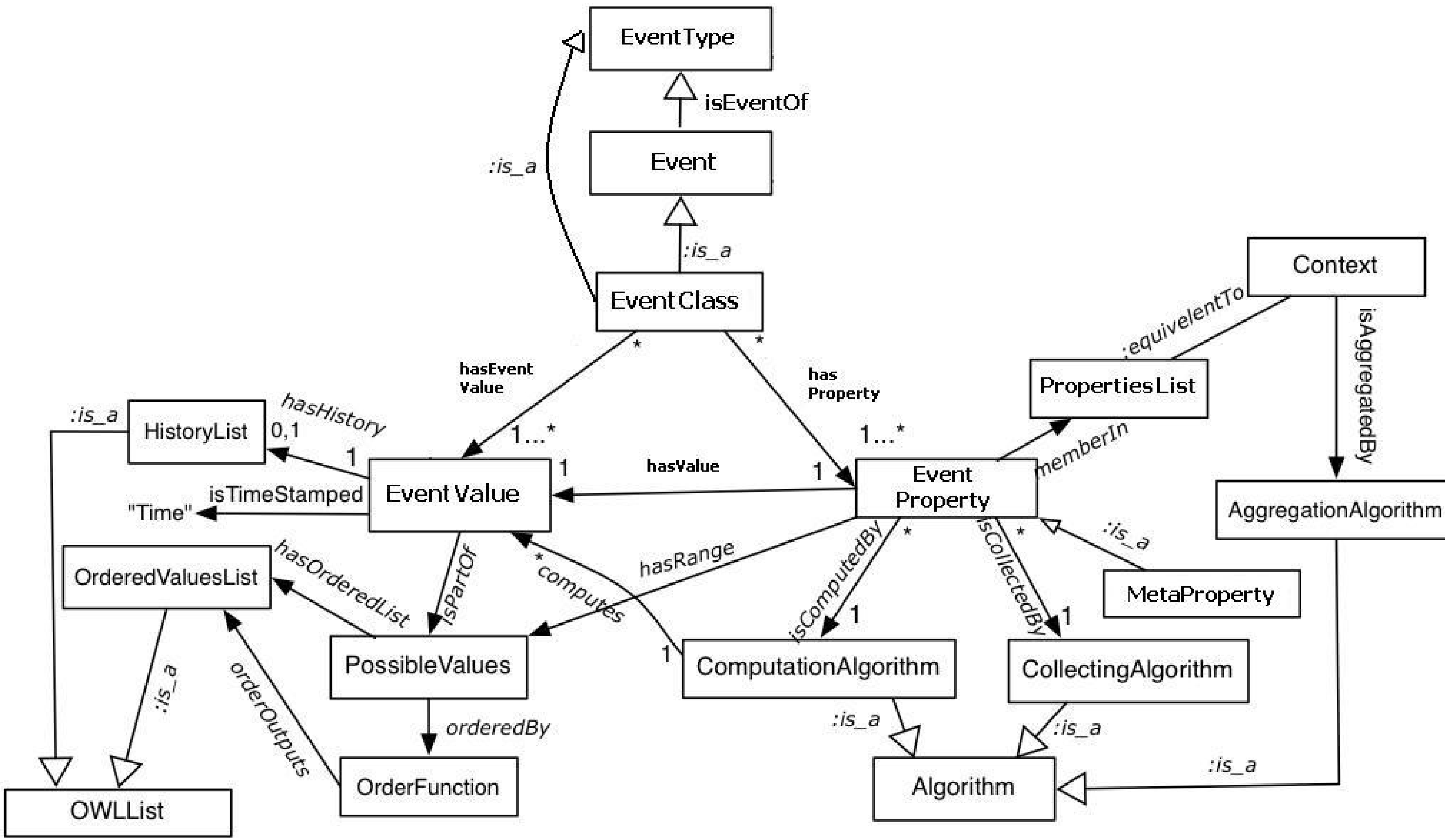


Defined
Event
Types

Event Class
Definition

Extended Event Meta Model Ontology

(with computational properties and complex value definitions)



Example - Typed Complex Event **Pattern** Definition

```
<Event key=“#ce2" type="&ruleml;ComplexEvent">
  <signature> <!-- pattern signature definition -->
    <Sequence>
      <signature>
        <Event type="&ruleml;SimpleEvent">
          <signature><Event>...event_A...</Event></signature>
        </Event>
      </signature>
      <signature><Event type="&ruleml;ComplexEvent" keyref="ce1"/></signature>
      <signature>
        <Event type="cbe:CommonBaseEvent" iri="cbe.xml#xpointer(//CommonBaseEvent)"/>
      </signature>
    </Sequence>
  </signature>
</Event>

<Event key=“#ce1">
  <signature> <!-- event pattern signature -->
    <Concurrent>
      <Event><meta><Time>...t3</Time></meta><signature>...event_B</signature></Event>
      <Event><meta><Time>...t3</Time></meta><signature>...event_C</signature></Event>
    </Concurrent>
  </signature>
</Event>
```

Event Pattern defining **Event Templates** signature

```
<Event key=“#e1” keyref=“#ce2”><content>…</content></Event>
```

Event Instance

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RuleML Sublanguages Customized by MYNG as Relax NG Schemas

ruleml.org/1.0/myng/

Selection Form

Instructions

Make a selection from the form below, then click "Refresh Schema" to update the Schema URL. The main module is also displayed below the form. To reset the form to the default (supremum) values, click "Reset Form".

Reset Form | Refresh Schema

Schema URL = http://ruleml.org/1.0/relaxng/schema_rnc.php?backbone=x3f&default=x7&termseq=x7&lng=x1&propo=x3ff&implies=x7&terms=xf3f&quant=x7&expr=xf&serial=xf

Expressivity "Backbone" (Check One)
- ○ Atomic Formulas
- ○ Ground Fact
- ○ Ground Logic
- ○ Datalog
- ○ Horn Logic
- ○ Disjunctive Logic
- ◉ Full First-Order Logic

Treatment of Attributes With Default Values (Check One)
- ○ Required to be Absent
- ○ Required to be Present
- ◉ Optional

Term Sequences: Number of Terms (Check One)
- ○ None
- ○ Binary (Zero or Two)
- ◉ Polyadic (Zero or More)

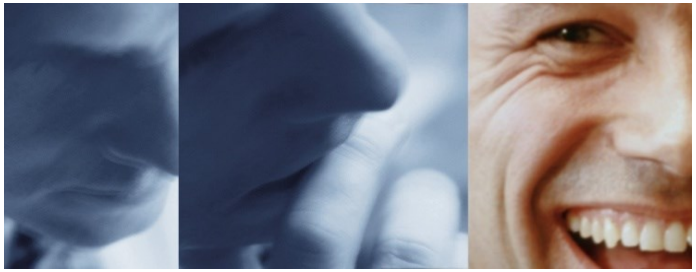
Language (Check One)
- ◉ English Abbreviated Names
- ○ English Long Names
- ○ French Long Names

Serialization Options (Check Zero or More)
- ☑ Unordered Groups
- ☑ Stripe-Skipping
- ☑ Explicit Datatyping
- ☑ Schema Location Attribute

Summary

- Fine grained **syntactic language configuration** (expressiveness) with MYNG (as Relax NG schemas)
- Intended semantics defined by **Semantic Profiles**
  - **Semantic Test Cases** for verification and validation
- Sorted Logic supports **Types** defined in external semantic ontologies and Meta Model vocabulary

- Towards joint standards for Deliberation, Reaction Rules



Thank you !

Questions?

Acknowledgement to the members of the Reaction RuleML technical group

RuleML Online Community

- RuleML MediaWiki (http://wiki.ruleml.org)
- Mailing lists (http://ruleml.org/mailman/listinfo)
- Technical Groups (http://wiki.ruleml.org/index.php/Organizational_Structure#Technical_Groups)
  - Uncertainty Reasoning
  - Defeasible Logic
  - Reaction Rules
  - Multi-Agent Systems
  - …
- RuleML sources are hosted on Github (https://github.com/RuleML)

Further Reading – (Reaction) RuleML

- Harold Boley, Adrian Paschke, Omair Shafiq: RuleML 1.0: The Overarching Specification of Web Rules. RuleML 2010: 162-178
  http://dx.doi.org/10.1007/978-3-642-16289-3_15
  http://www.cs.unb.ca/~boley/talks/RuleML-Overarching-Talk.pdf
- Adrian Paschke, Harold Boley, Zhili Zhao, Kia Teymourian and Tara Athan: Reaction RuleML 1.0: Standardized Semantic Reaction Rules, 6th International Conference on Rules (RuleML 2012), Montpellier, France, August 27-31, 2012
  http://link.springer.com/chapter/10.1007%2F978-3-642-32689-9_9
  http://www.slideshare.net/swadpasc/reaction-ruleml-ruleml2012paschketutorial
- Adrian Paschke: Tutorial on Semantic Complex Event Processing and Reaction RuleML, atDemAAL 2013 - Dem@Care Summer School on Ambient Assisted Living, 16-20 September 2013, Chania, Crete, Greece
  http://www.slideshare.net/swadpasc/dem-aal-semanticceppaschke
- Paschke, A., Boley, H.: Rule Markup Languages and Semantic Web Rule Languages, in Handbook of Research on Emerging Rule-Based Languages and Technologies: Open Solutions and Approaches, IGI Publishing, ISBN:1-60566-402-2, 2009
  http://www.igi-global.com/chapter/rule-markup-languages-semantic-web/35852
  Sample chapter: http://nparc.cisti-icist.nrc-cnrc.gc.ca/npsi/ctrl?action=rtdoc&an=18533385
- Paschke, A., Boley, H.: Rules Capturing Event and Reactivity, in Handbook of Research on Emerging Rule-Based Languages and Technologies: Open Solutions and Approaches, IGI Publishing, ISBN:1-60566-402-2, 2009
  http://www.igi-global.com/book/handbook-research-emerging-rule-based/465
  Sample Chapter: http://nparc.cisti-icist.nrc-cnrc.gc.ca/npsi/ctrl?action=rtdoc&an=16435934&article=0&fd=pdf
- Adrian Paschke and Harold Boley: Rule Responder: Rule-Based Agents for the Semantic-Pragmatic Web, in Special Issue on Intelligent Distributed Computing in International Journal on Artificial Intelligence Tools (IJAIT), V0l. 20,6, 2011
  https://www.researchgate.net/publication/220160498