r^3: Towards a Foundational Ontology for Reactive Rules

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Introduction

The **Semantic Web** is based on peer-to-peer communication between autonomous, and **autonomously developing, nodes** and it should support (not only querying, but also) propagation of knowledge and changes in a semantic way. Such **evolution** depends on the cooperation of nodes, and the heterogeneity of concepts for expressing **behavior** requires an appropriate handling on the semantic level. It is really unlikely that there will be a unique language for describing behavior throughout the entire Web.

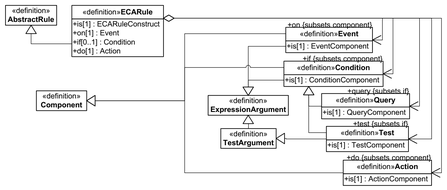
Heterogeneous Reactivity. A suitable common model (described in [4, 5, 2]) for dealing with such heterogeneity is provided by **reactivity** together with its formalization as *Event-Condition-Action (ECA) rules*, bearing: a clean separation between the *content* of a rule and the *generic semantics* of the rules themselves; an inherent loosely coupled nature, allowing the declarative combination of functionality from different Web sites (providing events and services).

Resourceful Reactive Rules. Much research effort is currently being targeted upon rule interchange formats, and upon defining rules for/about ontologies. In what concerns the former, most of proposals are XML-markup based and rely on specific abstract syntax, ignoring the fact that rules do not only operate on the Semantic Web, but are themselves also part of it. **Rules must be first class citizens of the Semantic Web**, especially if one wants to express and reason about evolution of behavior (towards **dynamic behavior** and **behavior policies**).

The r^3 Ontology. This calls for a **foundational ontology** for (ECA) rules that, according to the heterogeneity requirement previously identified, must allow also the description of different languages to be used and composed at the rule component level. The **OWL-DL r^3** ontology [2] (here presented using UML diagrams) is an intermediate step towards that goal reflecting work in progress in the r^3 project [9].

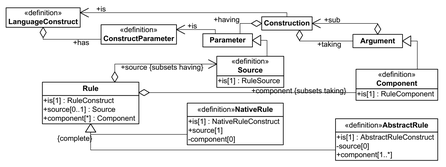
Describing Reactive Rules

The **component structure** of an ECA rule (which is shared by other kinds of reactive rules) is core to the r^3 ontology.



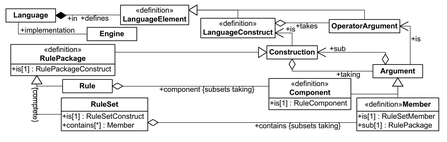

```
_:quotation-request-rule :is eca:rule;
 :on [:is eca:event;     :sub _:request-for-quotation];
 :if [:is eca:condition; :sub _:available-quotation;
 :do [:is eca:action;    :sub _:send-quotation].
```

Such a modular structure may be generalized to a **recursive term-structure** of constructions (using **parametric operators**).




```
_:available-quotation :is eca:collect-and-test;
 :taking [:is eca:collect; :sub _:quotation-data];
 :taking [:is eca:test;    :sub _:check-price]].
_:quotation-data :is fol:and;
 :taking [:is fol:some;    :sub _:flight-info];
 :taking [:is fol:more; :sub [:is fol:and;
 :taking [:is fol:some;    :sub _:get-client];
 :taking [:is fol:more;    :sub _:get-available-cars]]].
```

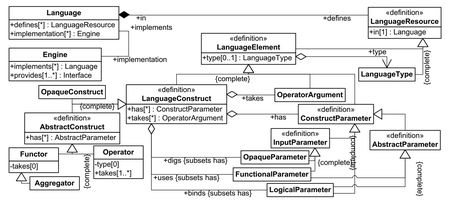
This term-structure is applied not only to rules but also to rule components and **rule sets**.



The building elements of such structure are described at a **meta-level** as language elements.
The constructs of a particular language are implemented by specific **engines** available on the Semantic Web.

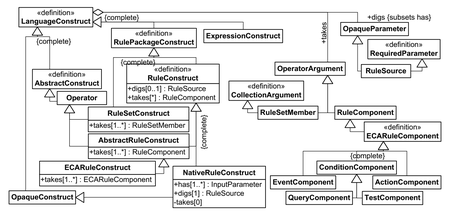
Describing Language Elements

Language constructs include **atomic** functors and **compositional** operators.




```
event:sequence a :Operator; :in event:algebra;
 :takes event:first, event:next.
travel:booking-place a :Functor; :in travel:domain;
 :binds travel:client, travel:flightnr, travel:seat.
travel:flight-info a :Functor; :in travel:domain;
 :uses travel:flightnr;
 :binds travel:date, travel:origin, travel:destination.
rental:request-quotation-for-flight a :Functor;
 :in rental:application
 :uses rental:client, rental:flightnr.
rental:get-client a :Functor; :in rental:application
 :uses rental:client;
 :binds rental:client-name,
   rental:favorite-class, rental:max-price.
rental:get-available-cars a :Functor;
 :in rental:application
 :uses rental:office, rental:date;
 :binds rental:car, rental:car-class, rental:price.
mail:send a :Functor; :in mail:library;
 :uses mail:from, mail:to, mail:subject, mail:body.
text:join a :Aggregator; :in text:library;
 :uses text:template, text:separator.
text:replace a :Aggregator; :in text:library;
 :uses text:template.
fol:and a :Operator; :in fol:algebra;
 :takes fol:some, fol:more.
```

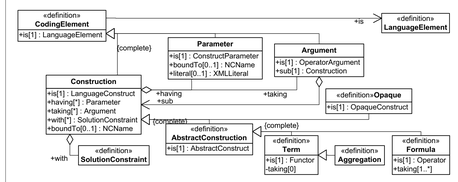
Abstract **parameters** may be **functional** (given) or **logical** (bound).




```
eca:rule a :ECARuleConstruct; :in eca:ml;
 :takes eca:event, eca:condition, eca:action.
eca:collect-and-test a :Operator; :in eca:ml;
 :takes eca:collect, eca:test.
eca:native a :NativeRuleConstruct; :in eca:ml;
 :uses eca:lang; :digs eca:source.
eca:opaque a :ExpressionConstruct; :in eca:ml;
 :uses eca:lang; :digs eca:literal.
eca:ml :defines
 eca:event, eca:condition, eca:action,
 eca:collect, eca:test.
```

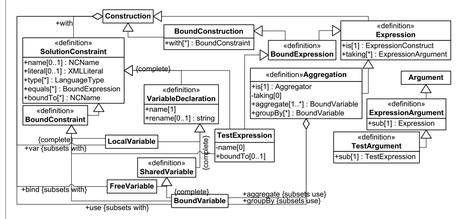
Opaque constructs allow ad-hoc textual languages (e.g. **database triggers**).

Describing Rule Components




```
_:request-quotation :is event:sequence;
 :taking [:is event:first; :sub [
   :is travel:booking-place;
   :having [:is travel:client; :boundTo "Mail"];
   :having [:is travel:flightnr; :boundTo "Flight"]]];
 :taking [:is event:next; :sub [
   :is rental:request-quotation-for-flight;
   :having [:is rental:client; :boundTo "Mail"];
   :having [:is rental:flightnr; :boundTo "Flight"]]].
_:get-client :is rental:get-client;
 :having [:is rental:client; :boundTo "Mail"];
 :having [:is rental:client-name; :boundTo "Client"];
 :having [:is rental:favorite-class; :boundTo "Class"];
 :having [:is rental:max-price; :boundTo "Max-Price"].
_:get-available-cars :is rental:get-available-cars;
 :having [:is rental:office; :boundTo "To"];
 :having [:is rental:date; :boundTo "Date"];
 :having [:is rental:car; :boundTo "Car"];
 :having [:is rental:car-class; :boundTo "Class"];
 :having [:is rental:price; :boundTo "Price"].
_:flight-info :is travel:flight-info;
 :having [:is travel:flightnr; :boundTo "Flight"];
 :having [:is travel:date; :boundTo "Date"];
 :having [:is travel:origin; :boundTo "From"];
 :having [:is travel:destination; :boundTo "To"].
```

Constructions may also include **variable declarations** and related **constraints**.




```
_:check-price :is eca:opaque;
 :literal "true";
 :use [:name "Price"];
 :use [:name "Max-Price"; :rename "MaxPrice"];
 :having [:is eca:lang;
   :literal "http://www.w3.org/XPath"];
 :having [:is eca:literal;
   :literal "$Price <= $MaxPrice".
_:send-quotation :is mail:send;
 :var [:name "Text"; :equals _:quotation-message];
 :having [:is mail:from; :boundTo "Rental-Mail"];
 :having [:is mail:to; :boundTo "Mail"];
 :having [:is mail:subject;
   :literal "Car Rental Quotation"];
 :having [:is mail:body; :boundTo "Text"].
_:quotation-message :is text:replace;
 :use [:name "Quotation" ];
 :var [:name "Priced-Cars";
   :equals [:is text:join;
     :aggregate [:name "Car"], [:name "Price"];
     :having [:is text:template;
       :literal "|Car|=|Price|"];
     :having [:is text:separator; :literal ", "];]];
 :aggregate
   [:name "Client"], [:name "Priced-Cars"],
   [:name "Flight"], [:name "Date"], [:name "To"];
 :having [:is text:template; :boundTo "Quotation"].
```

Present State

A **working prototype** [1] of the r^3 framework is available, for a previous version of this ontology, including a supporting library used to implement several component languages. A **new version** of the r^3 ontology is currently being defined allowing the description of derivation rules for higher-level events and actions. This new version will constitute the basis for a full **re-implementation** of the prototype.

Related Work. To the present, there are only two ontology proposals for describing rules: **WRL** [3] and **SBVR** [7]. The latter is not targeted to the Semantic Web but does address language heterogeneity, and does not exclude reactive rules (waiting on [6]). It is also worth mentioning that the **MARS** project [8] (with which r^3 shares its ideas) is pursuing a complementary approach to these issues at the OWL-Full level [2].

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