The RuleML Family of Web Rule Languages

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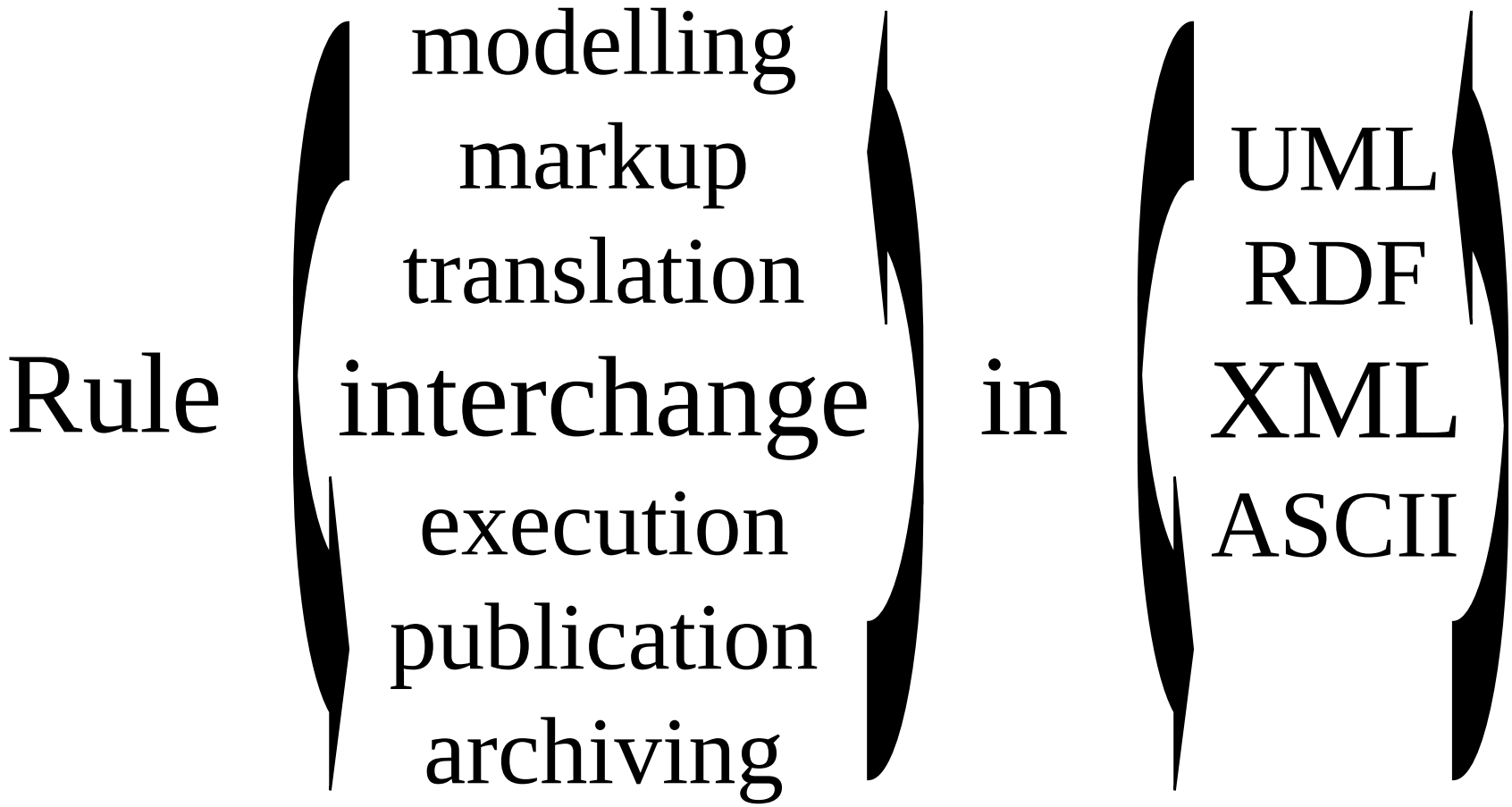
Introduction

- Rules are central to the Semantic Web
- Rule interchange in an open format is important for e-Business
- RuleML is the de facto open language standard for rule interchange/markup
- Collaborating with W3C (RIF), OMG (PRR, SBVR), OASIS, DARPA-DAML, EU-REWERSE, and other standards/gov'nt bodies

RuleML Enables ...



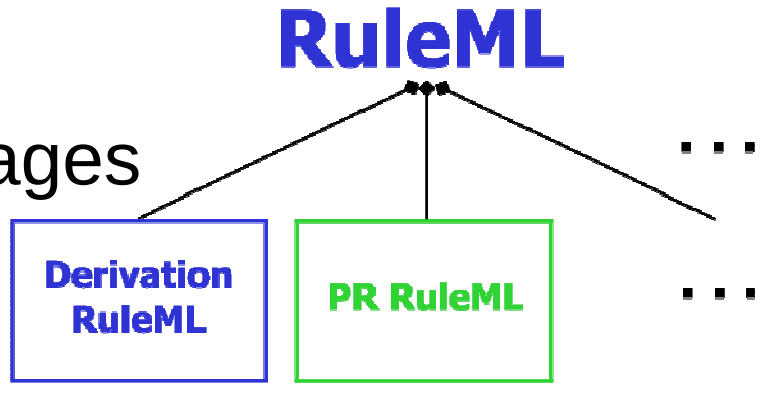
RuleML Identifies ...

- Expressive sublanguages
  - for Web rules
  - started with
    - *Derivation* rules: extend SQL views
    - *Reaction* rules: extend SQL triggers
  - to empower their subcommunities

RuleML Specifies ...

- Derivation rules via XML Schema:
  - All sublanguages:(OO) RuleML 0.91
  - First Order Logic: FOL RuleML 0.91
  - With Ontology language: SWRL 0.7
    - A Semantic Web Rule Language Combining OWL (W3C) and RuleML
  - With Web Services language: SWSL 0.9
- Translators in & out (e.g. Jess) via XSLT

Modular Schemas

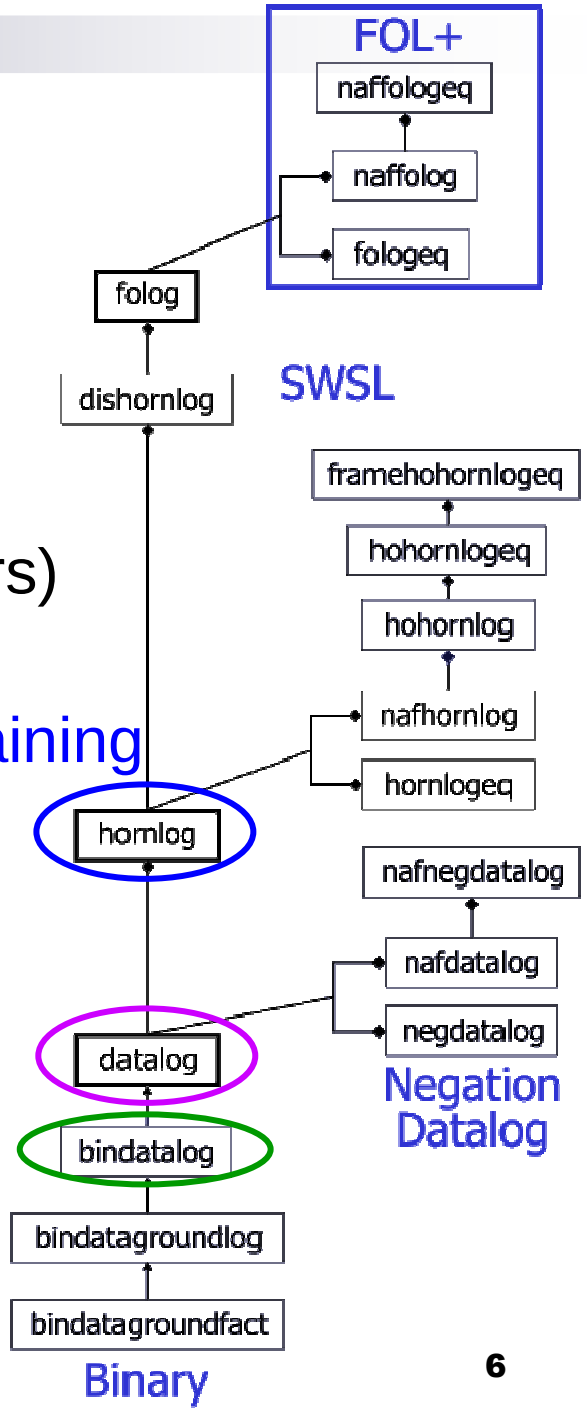


"RuleML is a **family** of sublanguages whose **root** allows access to the language as a whole and whose **members** allow to identify customized subsets of the language."

- RuleML: Rule Markup Language
  - RuleML derivation rules (shown here) and production rules defined in XML Schema Definition (XSD)
  - Each XSD of the family corresponds to the expressive class of a specific RuleML sublanguage
- The most recent schema specification of RuleML is always available at http://www.ruleml.org/spec
- Current release: RuleML 0.91
- Previews: http://wiki.ruleml.org/XSD_Workplan

Schema Modularization

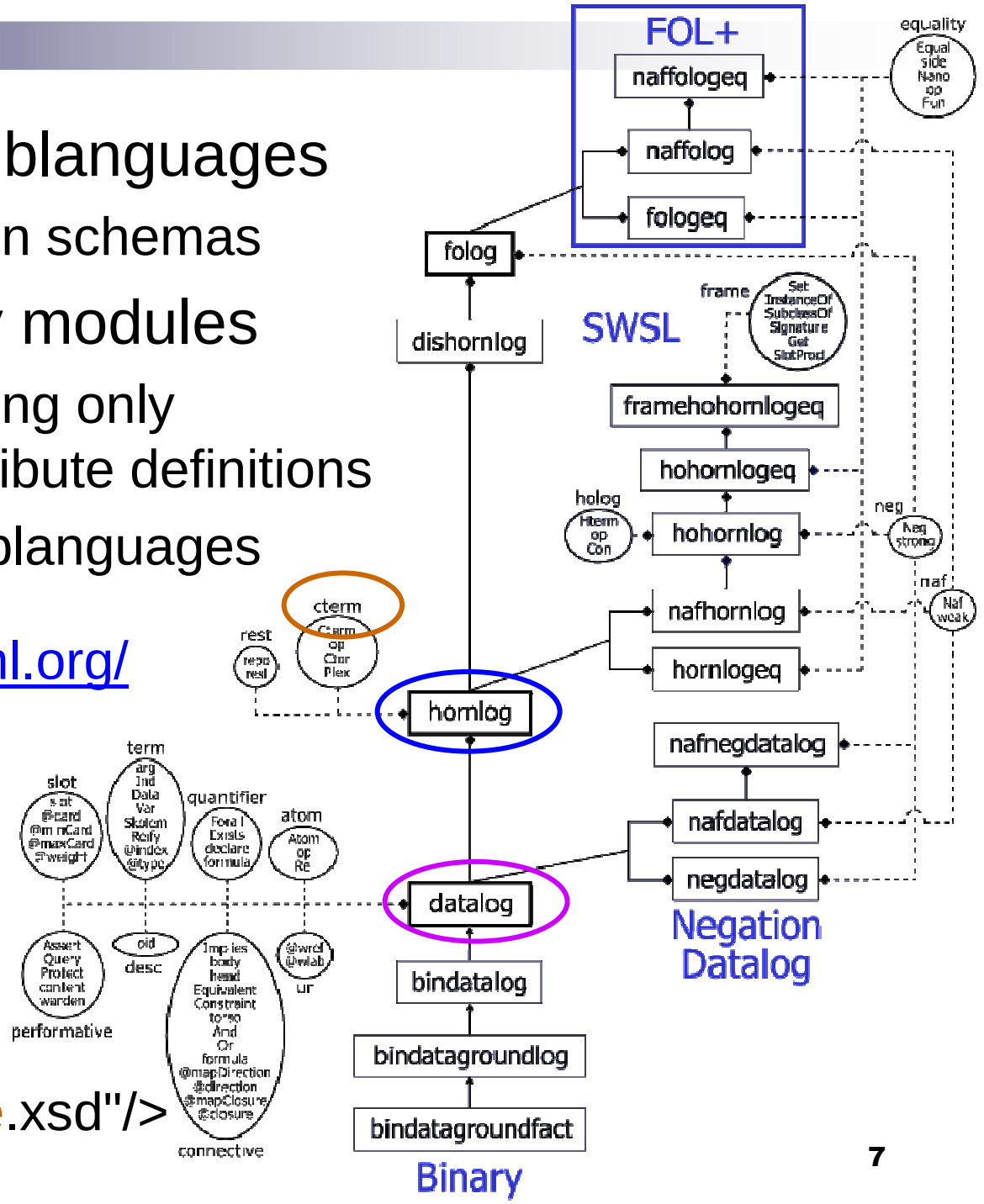
- XSD URIs identify expressive classes
  - Receivers of a rulebase can validate applicability of tools (such as Datalog vs. Hornlog interpreters)
  - Associated with semantic classes (such as function-free vs. function-containing Herbrand models)
- Modularization (Official Model)
  - Aggregation: e.g., Datalog *part of* Hornlog
  - Generalization: e.g., Bindatalog *is a* Datalog



- **Rectangles** are sublanguages
  - Inheritance between schemas
- **Ovals** are auxiliary modules
  - Elementary, including only element and/or attribute definitions
  - Become *part of* sublanguages

E.g., in http://www.ruleml.org/0.91/xsd/hornlog.xsd

```
<xs:redefine
schemaLocation=
"datalog.xsd">
<xs:include
schemaLocation=
"modules/cterm_module.xsd"/>
```

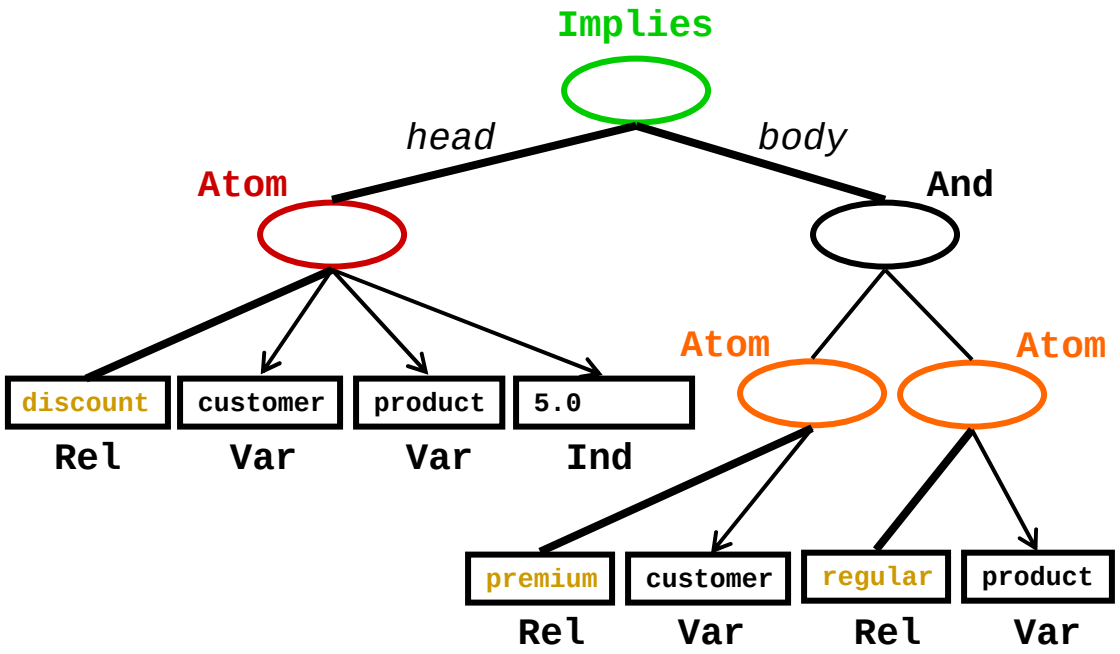


Bring Datalog to the Semantic Web

- Start with n-ary relations (not binary properties)
- Keep **`Var`**iable typing optional (reuse RDFS' subClassOf taxonomies as sort lattices)
- Allow signature declarations of arities and types
- Employ function-free facts as well as Horn rules (rather than 1st: RDF descriptions; 2nd: RDF rules)
- Use function-free Herbrand model semantics (querying stays decidable)
- Provide three syntactic levels:
  - User-oriented: Prolog-like, but with "?"-variables
  - Abstract: MOF/UML diagrams
  - XML serialization: Datalog RuleML

Business Rule: Positional

"The **discount** for a *customer* buying a *product* is 5 percent if the *customer* is **premium** and the *product* is **regular**."



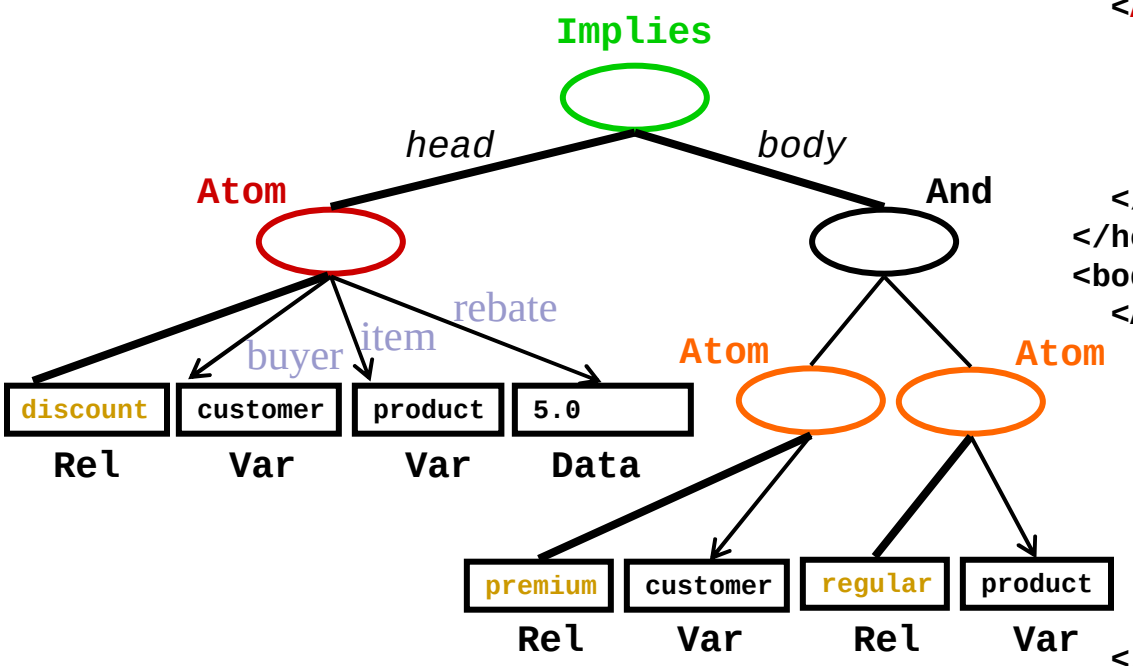

```
<Implies>
  <head>
    <Atom>
      <Rel>discount</Rel>
      <Var>customer</Var>
      <Var>product</Var>
      <Ind>5.0</Ind>
    </Atom>
  </head>
  <body>
    <And>
      <Atom>
        <Rel>premium</Rel>
        <Var>customer</Var>
      </Atom>
      <Atom>
        <Rel>regular</Rel>
        <Var>product</Var>
      </Atom>
    </And>
  </body>
</Implies>
```

Extend Datalog for the Semantic Web (I)

- Allow slots as name**->**filler pairs in **`Atom`**s (cf. F-logic's methods and RDF's properties)
- Extend optional types and signatures for slots
- Add optional object identifiers (**`oid`**s) to atoms
- Separate **`Data`** literals from **`Ind`**ividual constants

Business Rule: Slotted (for OO)

"The **discount** for a *customer* buying a *product* is 5 percent if the *customer* is **premium** and the *product* is **regular**."




```
<Implies>
  <head>
    <Atom>
      <Rel>discount</Rel>
      <slot><Ind>buyer</Ind><Var>customer</Var></slot>
      <slot><Ind>item</Ind><Var>product</Var></slot>
      <slot><Ind>rebate</Ind><Data>5.0</Data></slot>
    </Atom>
  </head>
  <body>
    <And>
      <Atom>
        <Rel>premium</Rel>
        <Var>customer</Var>
      </Atom>
      <Atom>
        <Rel>regular</Rel>
        <Var>product</Var>
      </Atom>
    </And>
  </body>
</Implies>
```

Extend Datalog for the Semantic Web (II)

- Permit IRI webizing for **`Data`** (XML Schema Part 2), **`Ind`**ividuals (RDF's **`resource`**s), **`Rel`**ations, **`slot`** names, types (RDFS' classes), and **`oid`**s (RDF's **`about`**)
- Introduce **`Module`** (scope) construct for clauses (cf. RDF's named graphs)
- Add scoped-default (**`Naf`**), strong (**`Neg`**), scoped-default-of-strong negation (unscoped: cf. ERDF)
- Integrate with Description Logics
  - Homogeneous (SWRL, Datalog RuleML + OWL-DL)
  - Hybrid (AL-log, Datalog^{DL}, DL+log, ...)

Bring Horn Logic to the Semantic Web

- Augment Datalog with uninterpreted **`Fun`**ctions and their **`Expr`**essions; also for extended Datalog
- Augment Datalog's Herbrand model semantics with such **`Fun`**ctions (querying becomes undecidable)
- Extend Datalog syntaxes
  - XML Schema of Hornlog RuleML inherits and augments XML Schema of Datalog RuleML
- Add **`Equal`**ity and **`in`**terpreted **`Fun`**ctions (XML serialization: attribute **`in="yes"`**)
- Reuse XQuery/XPath functions and operators as built-ins

Specify a First-Order Logic Web Language

- Layer on top of either
  - Disjunctive Datalog: **`Or`** in the head generalizing Datalog
  - Disjunctive Horn Logic: **`Or`** in head of near-Horn clauses
- Alternatively, layer on top of either
  - Disjunctive Datalog with restricted strong **`Neg`**ation
  - Disjunctive Horn Logic with restricted strong **`Neg`**
- Permit unrestricted **`Or`**, **`And`**, strong **`Neg`**, and quantifiers **`Forall`** and **`Exists`** to obtain FOL
- Use semantics of classical FOL model theory
- Extend Hornlog RuleML syntax to FOL RuleML

Approach Production and Reaction Rules

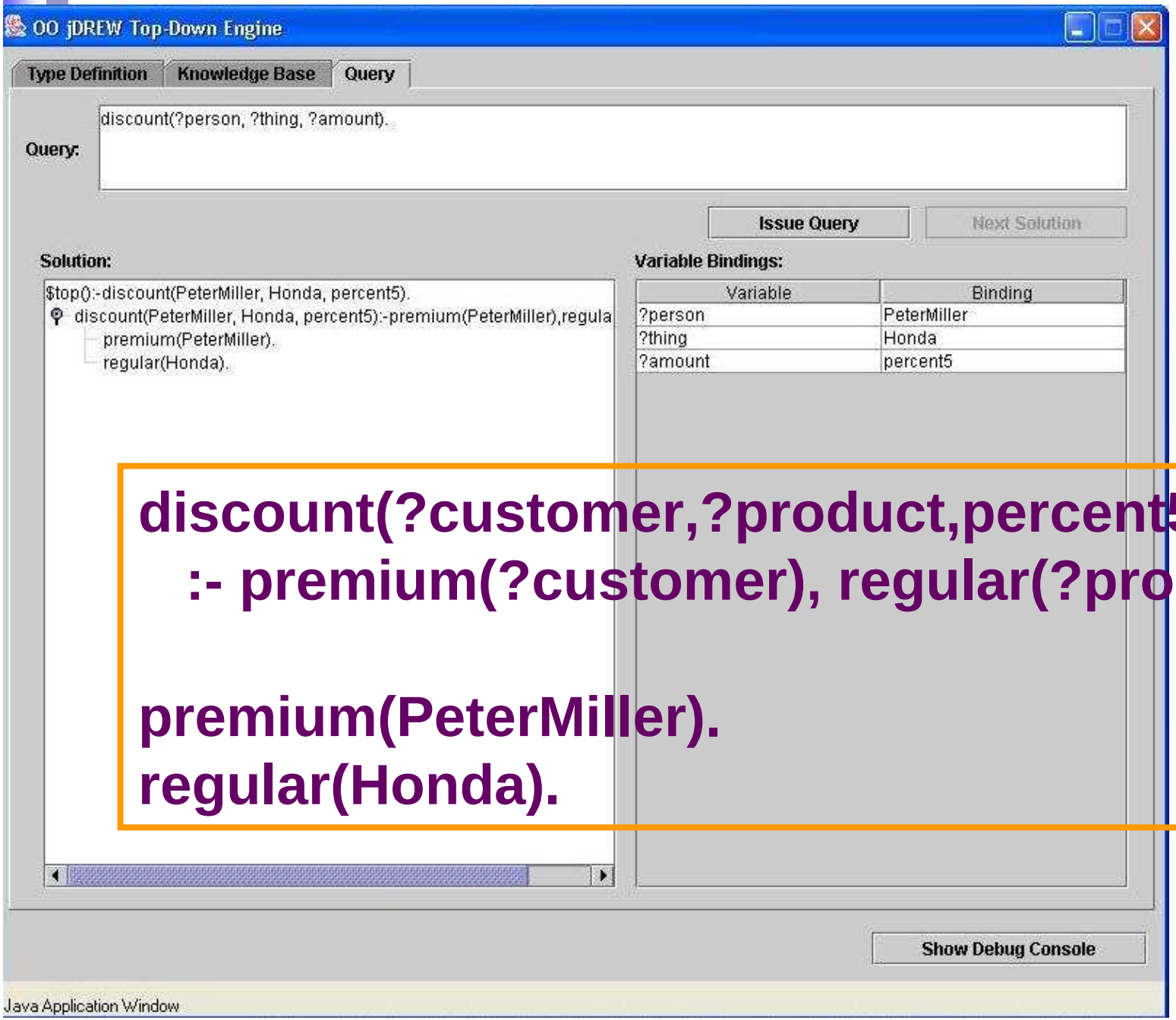
- Share Condition (C) part with earlier languages as proposed for the RIF Condition Language
- Develop Action (A) part of Production Rules via a taxonomy of actions on KBs (Assert, Retract, ...), on local or remote hosts, or on the surroundings
- Develop Event (E) part of Reaction Rules via a corresponding taxonomy
- Create CA and ECA families bottom-up and map to relevant languages for Semantic Web Services
- Serialized: <**Reaction**> E C A </**Reaction**>
- See http://ibis.in.tum.de/research/ReactionRuleML TG

Bidirectional Interpreters in Java

- Two varieties of reasoning engines
  - **T**op-**D**own: backward chaining
  - **B**ottom-**U**p: forward chaining
- jDREW: *Java Deductive Reasoning Engine for the Web* includes both TD and BU
  http://www.jdrew.org
- OO jDREW: *Object-Oriented* extension to jDREW
  http://www.jdrew.org/oojdrew
- Java Web Start online demo available at
  http://www.jdrew.org/oojdrew/demo.html

OO jDREW Slots

- Normalized atoms and complex terms
  - **`oid`**s (object identifier)
  - Positional parameters (in their original order)
  - Positional rest terms
  - Slotted parameters (in the order encountered)
  - Slotted rest terms
- Efficient unification algorithm
  - Linear O(m+n): instead of O(m*n)
    - No need for positional order
    - Slots internally sorted
  - Steps:
    - Scan two lists of parameters
      - Matching up roles and positions for positional parameters
      - Unifying those parameters
    - Add unmatched roles to list of rest terms
    - Generate dynamically a Plex (RuleML's closest equivalent to a list) for a collection of rest terms

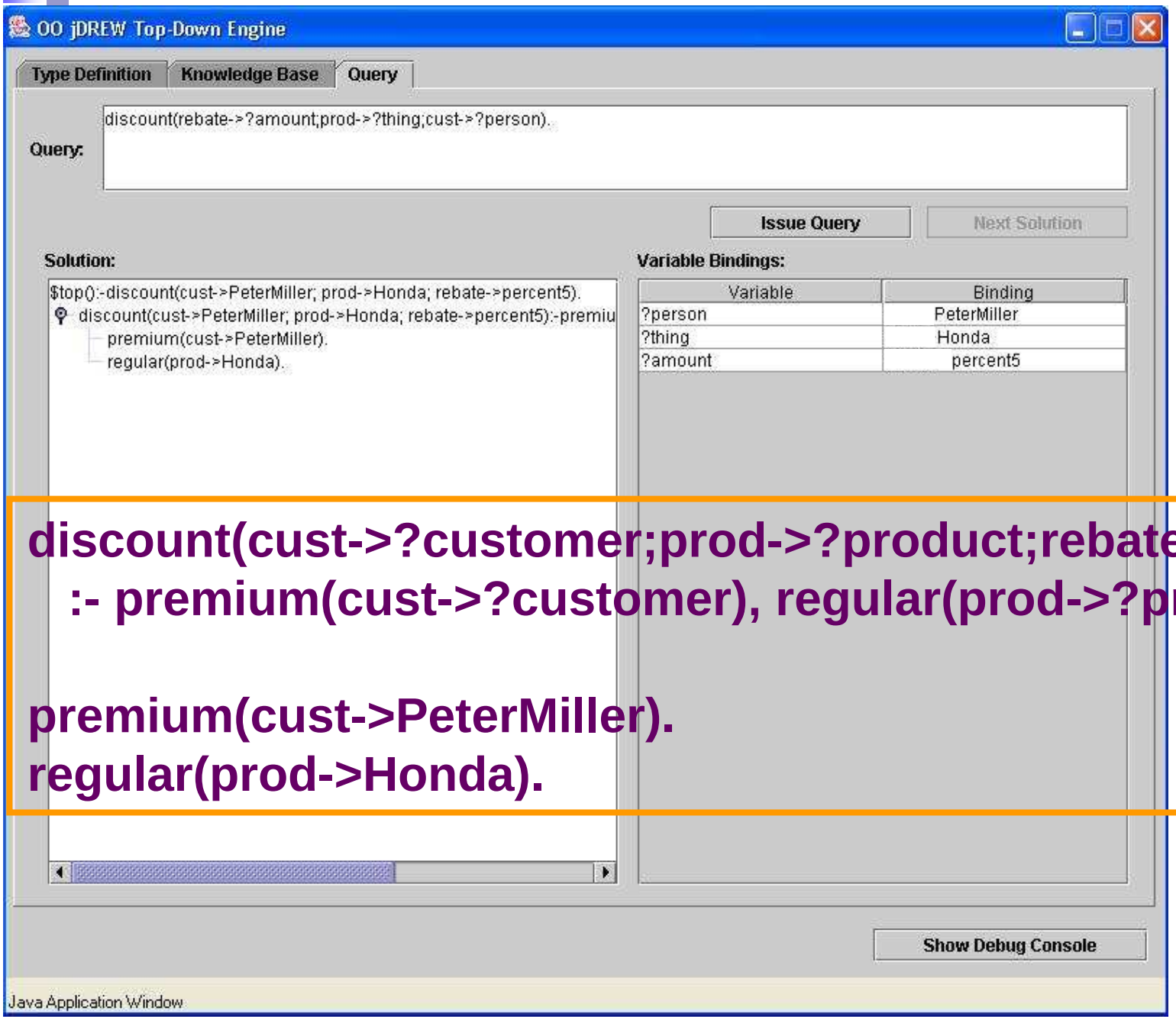


positional

POSL syntax

```
discount(?customer,?product,percent5)
   :- premium(?customer), regular(?product).

premium(PeterMiller).
regular(Honda).
```



slotted

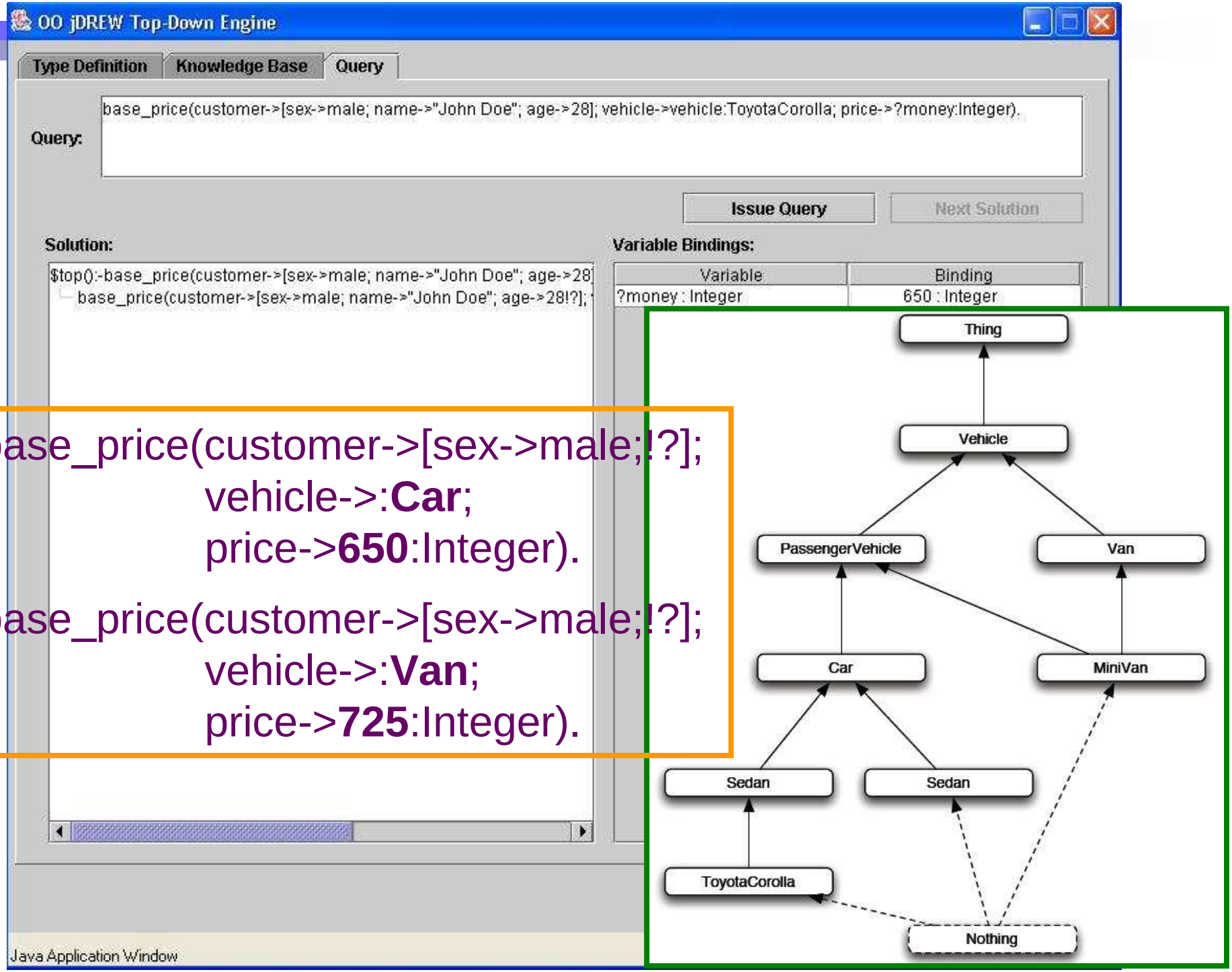
POSL syntax

```
discount(cust->?customer;prod->?product;rebate->percent5)
   :- premium(cust->?customer), regular(prod->?product).

premium(cust->PeterMiller).
regular(prod->Honda).
```

OO jDREW Types

- Order-sorted type system
  - RDF Schema: lightweight taxonomies of the Semantic Web
  - To specify a partial order for a set of classes in RDFS
- Advantages
  - Having the appropriate types specified for the parameters
  - To restrict the search space
  - Faster and more robust system than when reducing types to unary predicate calls in the body
- Limitations
  - Only modeling the taxonomic relationships between classes
  - Not modeling properties with domain and range restrictions



base_price(customer->[sex->male;!?];
vehicle->:**Car**;
price->**650**:Integer).

base_price(customer->[sex->male;!?];
vehicle->:**Van**;
price->**725**:Integer).

Conclusions

- RuleML is modular family, whose root allows to access the language as a whole and whose members allow customized subsets
- New members joining, e.g. Fuzzy RuleML
- Concrete & abstract syntax of RuleML
  - Specified by modular XSD (shown here) & MOF
- Formal semantics of OO Hornlog RuleML
  - Implemented by OO jDREW BU & TD
- Interoperability/Interchange of/with RuleML
  - Realized by translators, primarily via XSLT