Rules and DAML:
Description Logic Programs, Rule-based Semantic Web Services, their Application Scenarios; and RuleML Update

Presentation for DAML PI Meeting,
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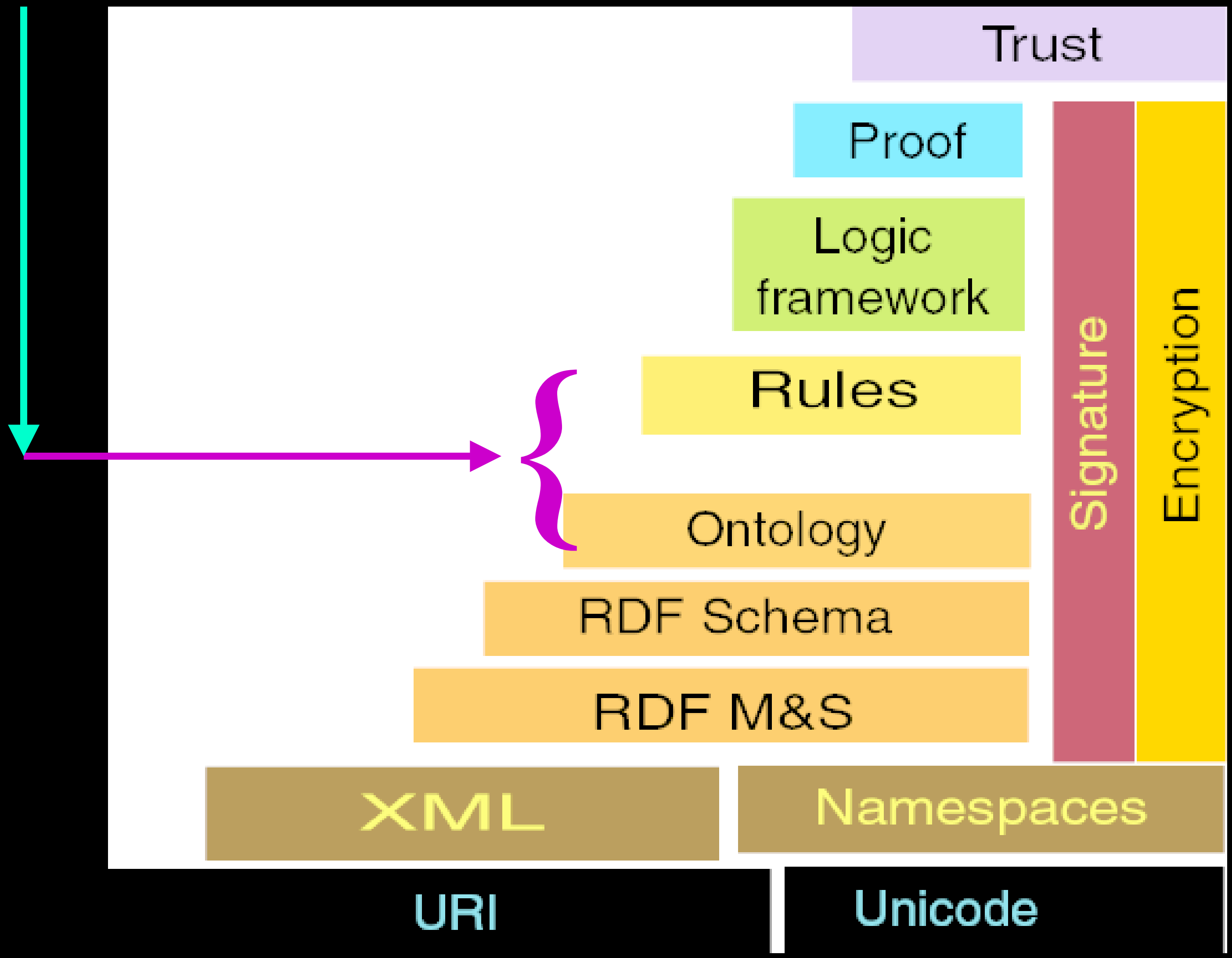
What is "DAML Rules"?

- Answer 1 (general):
  - new stuff about rules that relates specifically to the DAML program, including to DAML+OIL, DAML-Services, and their application scenarios

- Answer 2 (narrower):
  - the hybridization of DAML+OIL with Logic Program rules
    - original aim: extend expressiveness of DAML KR beyond DAML+OIL
      - for defining ontologies, and for rules plus ontologies
    - current thrust focuses on *Description Logic Programs* as KR

Motivation from Semantic Web "Stack"



[Diagram http://www.w3.org/DesignIssues/diagrams/sw-stack-2002.png is courtesy Tim Berners-Lee]

Outline:

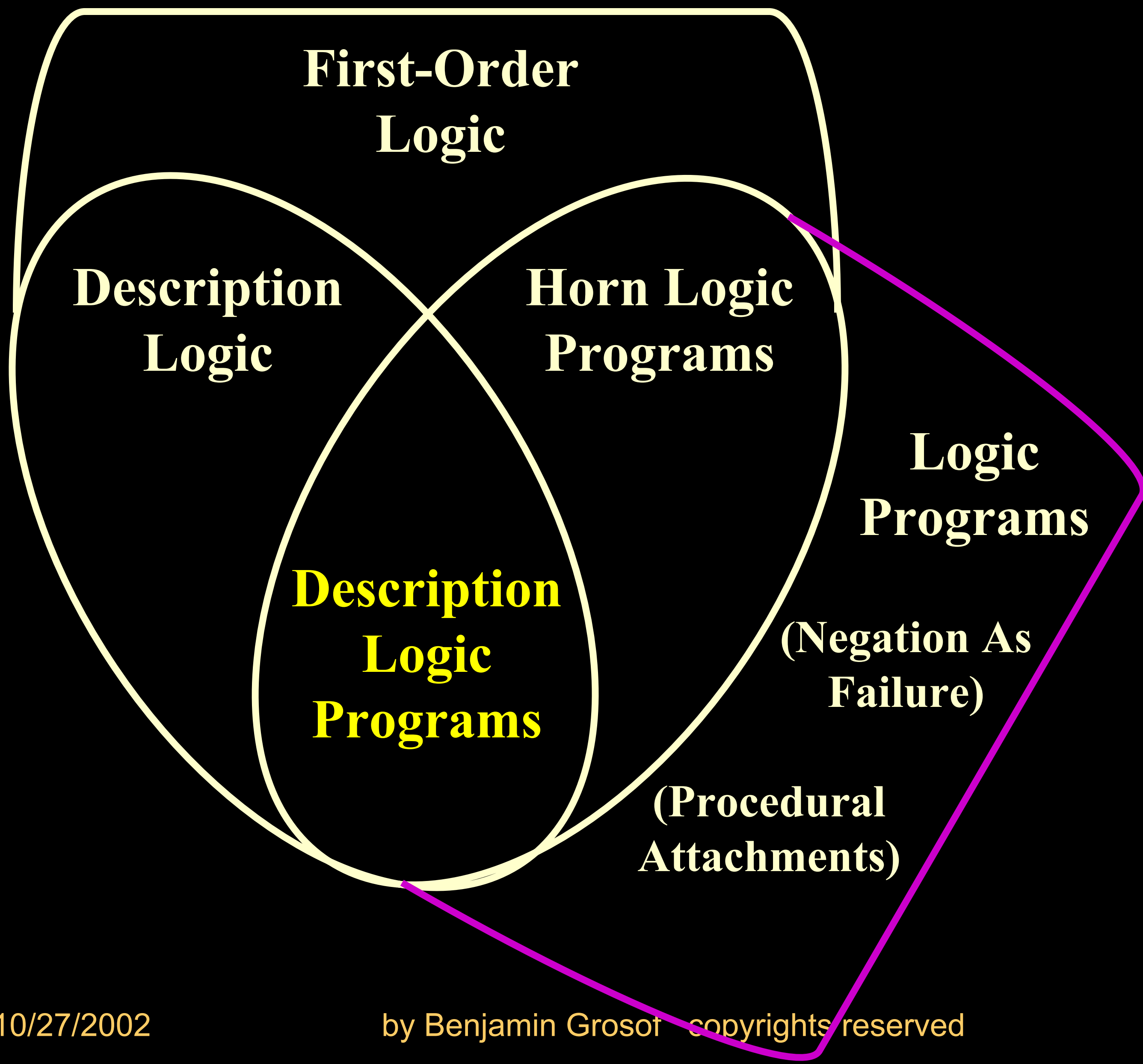
Rules wrt DAML+OIL, DAML-Services

- Description Logic Programs (DLP)
- Rule-based Semantic Web Services (RSWS)
- Application Scenarios
- Other misc. on Rules and DAML
- RuleML update (brief)

Description Logic Programs (DLP)

- Status: [Grosof & Horrocks 10/02] working paper, Joint Committee discussions, including early use cases.
- Goal: understand relationship between DL and LP/HornFOL as KR's
  - Insight: expressive intersection is also a key to expressive combination/union
- 1st step: expressive intersection of DL and Logic Programs = "Description Logic Programs" (or "Description Rules")

Venn Diagram: Expressive Overlaps among KR's



LP as a superset of DLP

- “Full” LP, including with non-monotonicity and procedural attachments, can thus be viewed as including an “ontology sub-language”, namely the DLP subset of DL.

Candidate: First Order Logic

- FOL has practical and expressive drawbacks for union of DL and Rules:
  - Intractable
  - Lacks non-monotonicity and procedural attachments
  - Unfamiliar to mainstream software engineers

- Variant of DLP: "Horn Description Logic (HDL)"
  - Intersection of Horn Logic and Description Logic
  - Subset of FOL

- (general concept of "Description Rules": covers DLP or HDL)

Overview of DLP Features

- Essentially, DLP captures RDFS subset of DL -- plus a bit more.
- RDFS subset of DL permits the following statements:
  - Class C is Subclass of class D.
  - Domain of property P is class C.
  - Range restriction on property P is class D.
  - Property P is Subproperty of property Q.
  - a is an instance of class C.
  - (a,b) is an instance of property P.
- DLP also captures:
  - Using the Intersection connective (conjunction) in class descriptions
  - Stating that a property P is Transitive.
  - Stating that a property P is Symmetric.
- DLP can *partially* capture: most other DL features.
- Relevant technical issue in LP:
  - treatment of equality, e.g., uniqueness of names.

Examples of DL beyond DLP

- DLP is a *strict* subset of DL.
- Examples of DL that is not (completely) representable in DLP:
  - State a subclass of a complex class expression which is a disjunction. E.g.,
    - $(\text{Human} \cap \text{Adult}) \subseteq (\text{Man} \cup \text{Woman})$
  - State a subclass of a complex class expression which is an existential. E.g.,
    - $\text{Radio} \subseteq \exists\ \text{hasSpeaker.Tuner}$
- Why not? Because: LP/Horn, and thus DLP, cannot represent a "disjunction in the head".

Examples of LP beyond DLP

- DLP is a *strict* subset of Horn LP.
- Examples of Horn LP that are not (completely) representable in DLP:
  - A rule involving multiple variables. E.g.,
    - PotentialLoveInterestBetween(?X,?Y)

      ← Man(?X) /\ Woman(?Y).
  - Chaining (besides simple transitivity) to derive values of Properties. E.g.,
    - InvolvedIn(?Company, ?Industry)

      ← Subsidiary(?Company, ?Unit)

      /\ AreaOf(?Unit, ?Industry).
- Why not? Essentially because: Decidability of DLs crucially dependent on tree model property.
  - Intuition: DL's not used to represent "more than one free variable at a time".

Benefits: What DLP Enables, in Principle

- LP rules "on top of" DL ontologies.
- Translation of LP rules to/from DL ontologies.
- Use of efficient LP rule/DBMS engines for DL fragment.
- Development of ontologies in LP.
- Development of rules in DL.
- Translation of LP conclusions to DL.
- Translation of DL conclusions to LP.

DL Task Scenarios / Use Cases -- how well do they map to Rules?

- 1. Infer Categorization
  - Rules appear to often handle this well.
- 2. Infer Subsumptions
  - Rules appear to often be more awkward.
- 3. Configuration: seems to involve both categorization and subsumption.

LP Task Scenarios / Use Cases

- Key aim: import DL ontologies into LP rulebase.
-
- ⇒ Consistency of the result/merge is an issue.

- Ways to achieve robustness:
  - 1. Use DLP for ontologies, rather than full DL.
  - 2. Exploit LP's nonmonotonic expressiveness:
    - Negation as failure; or more generally:
    - Courteous LP's prioritized conflict handling

Hybrid DL+LP Task Scenarios/Use-Cases

- 1. Service descriptions combining LP rules and DL ontologies
- 2. Rules for knowledge translation: e.g.,
  - translating/merging ontologies (or rules)

Related Work to DLP

- CARIN [Halevy et al, late 90's] on extending DL with some aspects of LP. For DL-ish tasks.
- [Antoniou 2002] on Defeasible Logic rules + Description Logic (variant) ontologies

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Rule-based Semantic Web Services

- Rules/LP in appropriate combination with DL as KR, for RSWS
  - DL good for categorizing: a service overall, its inputs, its outputs
- Rules to describe service process models
  - rules good for representing:
    - preconditions and postconditions, their contingent relationships
    - contingent behavior/features of the service more generally,
      - e.g., exceptions/problems
  - familiarity and naturalness of rules to software/knowledge engineers
- Rules to specify deals about services: cf. e-contracting.

Rule-based Semantic Web Services

- Rules often good to executably specify service process models
  - e.g., business process automation using procedural attachments to perform side-effectful/state-changing actions ("effectors" triggered by drawing of conclusions)
  - e.g., rules obtain info via procedural attachments ("sensors" test rule conditions)
  - e.g., rules for knowledge translation or inferencing
  - e.g., info services exposing relational DBs

- Infrastructural: rule system functionality as services:
  - e.g., inferencing, translation

Application Scenarios for Rule-based Semantic Web Services

- SweetDeal [Grosof & Poon 2002] configurable reusable e-contracts:
  - LP rules about agent contracts with exception handling
  - … on top of DL ontologies about business processes;
  - *a scenario motivating DLP*

- Other:
  - Trust management / authorization (Delegation Logic) [Li, Grosof, & Feigenbaum 2000]
  - Financial knowledge integration (ECOIN) [Firat, Madnick, & Grosof 2002]
  - Privacy policies (P3P APPEL)
  - Business policies, more generally

Example Contract Proposal with Exception Handling
Represented using RuleML & DAML+OIL, Process Descriptions

Using concise text syntax

(SCLP textfile format)

for concise human reading

```
buyer(co123,acme);
seller(co123,plastics_etc);
product(co123,plastic425);
price(co123,50);
quantity(co123,100);
http://xmlcontracting.org/sd.daml#Contract(co123);
http://xmlcontracting.org/sd.daml#specFor(co123,co123_process);
http://xmlcontracting.org/sd.daml#BuyWithBilateralNegotiation(co123_process);
http://xmlcontracting.org/sd.daml#result(co123,co123_res);
shippingDate(co123,3); // i.e. 3 days after order placed
// base payment = price * quantity
payment(?R,base,?Payment) <-
  http://xmlcontracting.org/sd.daml#result(co123,?R) AND
  price(co123,?P) AND quantity(co123,?Q) AND
  multiply(?P,?Q,?Payment) ;
```


SCLP TextFile Format for (Daml)RuleML

```
payment(?R,base,?Payment) <-
http://xmlcontracting.org/sd.daml#result(co123,?R) AND
price(co123,?P) AND quantity(co123,?Q) AND
multiply(?P,?Q,?Payment) ;
```

```
<drm:imp>
  <drm:_head> <drm:atom>
     <drm:_opr><drm:rel>payment</drm:_opr></drm:rel>    <drm:tup>
     <drm:var>R</drm:var> <drm:ind>base</drm:ind> <drm:var>Payment</drm:var>
  </drm:tup></drm:atom> </drm:_head>
  <drm:_body>
   <drm:andb>
     <drm:atom> <drm:_opr>
       <drm:rel href= "http://xmlcontracting.org/sd.daml#result"/>
         </drm:_opr> <drm:tup>
           <drm:ind>co123</drm:ind> <drm:var>Cust</drm:var>
          </drm:tup> </drm:atom>

... </drm:andb> </drm:_body>  </drm:imp>
```

drm = namespace for damlRuleML

Example Contract Proposal, Continued: lateDeliveryPenalty exception handler module

```
lateDeliveryPenalty_module {
// lateDeliveryPenalty is an instance of PenalizeForContingency
//   (and thus of AvoidException, ExceptionHandler, and Process)
http://xmlcontracting.org/pr.daml#PenalizeForContingency(lateDeliveryPenalty) ;
// lateDeliveryPenalty is intended to avoid exceptions of class
// LateDelivery.
http://xmlcontracting.org/sd.daml#avoidsException(lateDeliveryPenalty,
  http://xmlcontracting.org/pr.daml#LateDelivery);
// penalty = - overdueDays * 200 ; (negative payment by buyer)
<lateDeliveryPenalty_def> payment(?R, contingentPenalty, ?Penalty) <-
  http://xmlcontracting.org/sd.daml#specFor(?CO,?PI) AND
  http://xmlcontracting.org/pr.daml#hasException(?PI,?EI) AND
  http://xmlcontracting.org/pr.daml#isHandledBy(?EI,lateDeliveryPenalty) AND
  http://xmlcontracting.org/sd.daml#result(?CO,?R) AND
  http://xmlcontracting.org/sd.daml#exceptionOccurred(?R,?EI) AND
  shippingDate(?CO,?CODate) AND shippingDate(?R,?RDate) AND
  subtract(?RDate,?CODate,?OverdueDays) AND
  multiply(?OverdueDays, 200, ?Res1) AND multiply(?Res1, -1, ?Penalty) ;
}
<lateDeliveryPenaltyHandlesIt(e1)> // specify lateDeliveryPenalty as a handler for e1
 http://xmlcontracting.org/pr.daml#isHandledBy(e1,lateDeliveryPenalty);
```


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Other Misc. on Rules and DAML

- DAML+OIL syntax for RuleML: DamlRuleML; implemented in SweetJess
- Inclusion: DAML Includes, XIncludes
- Queries: DAML Query Language (DQL), ...
- Explanations and justifications

RuleML Update

- Overall: more tools, more participants.
- Situated courteous LP (SCLP) as extension of spec.
  - Implemented in SweetRules [Grosof 2001] inferencing and translation.
- DAMLRuleML draft spec.: DAML+OIL spec. for RuleML's syntax.
  - Implemented in SweetJess [Grosof, Gandhe, and Finin 2002].
- SweetJess translator of SCLP RuleML to/from Jess, inferencing via Jess.
  - 1^{st} bridge between Prolog/RDBMS and OPS5/ECA.
- Reactive rules subgroup effort launching.
- Applications:
  - Configurable reusable e-contracts (SweetDeal).
  - Ontology-based financial knowledge integration (ECOIN).
- Oasis interest in "Policy RuleML" (tentative name) as possible TC.
  - RuleML for interchange between policy languages.
- Plan to engage on W3C front, as well.
- Events aimed for in 2003: W3C Plenary, WWW Conf., ISWC.

Other Issues in Rules

- Relationship to XQuery, RDF Query
- *(Open discussion….)*

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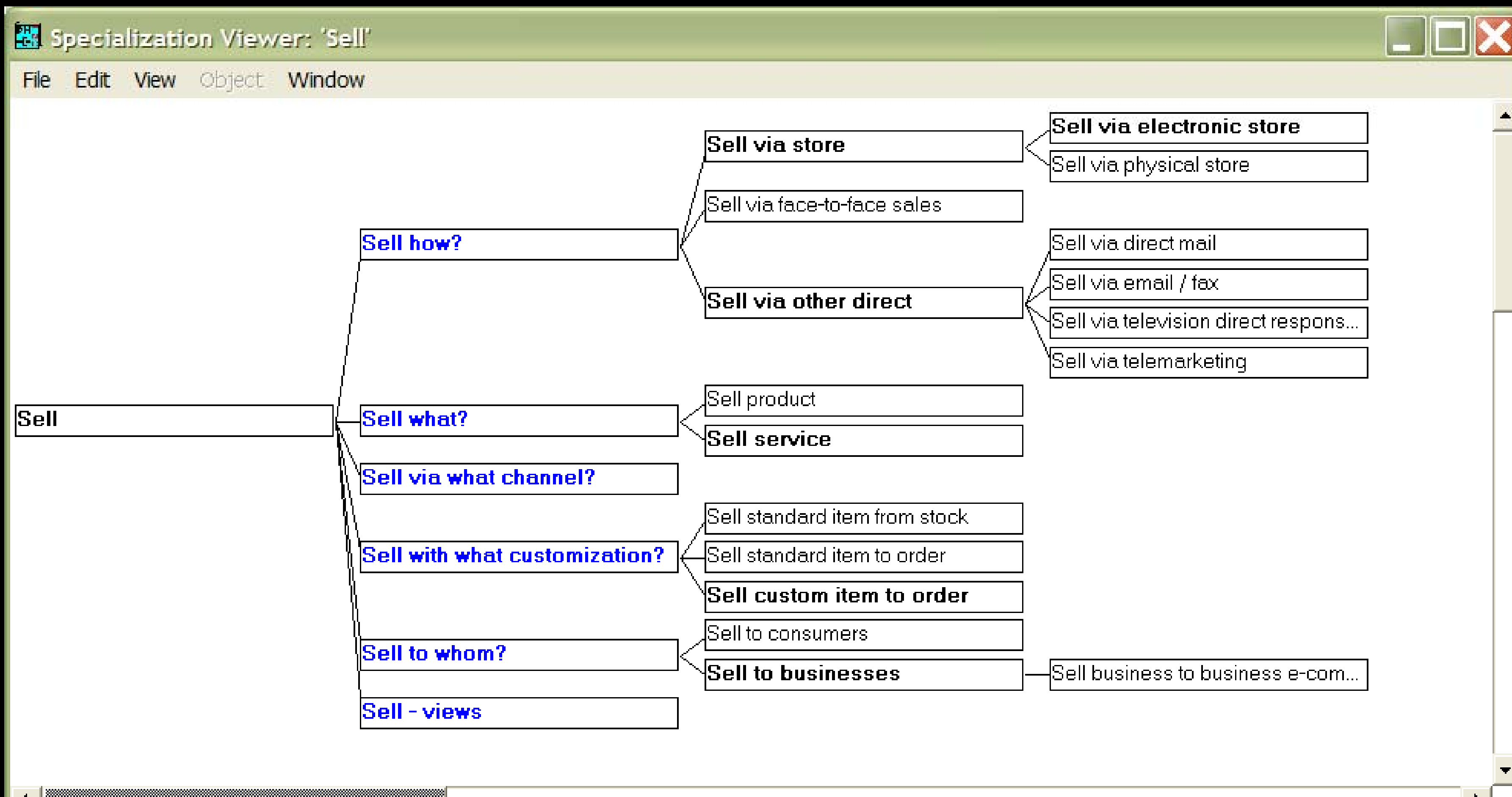
- Grosof, Benjamin and Gandhe, Mahesh and Finin, Tim. "SweetJess: Translating DamlRuleML to Jess". Proc. Intl. Wksh. on Rule Markup Languages for Business Rules on the Semantic Web, held 6/02 at the 1st Intl. Semantic Web Conf. (ISWC-2002).
- Levy, Alon and Rousset, Marie-Christine. "CARIN: A Representation combining Horn Rules and Description Logic." *Artificial Intelligence* 104(1-2), 1998. (Note: Alon has since changed his surname to "Halevy".)
- Li, Ninghui and Grosof, Benjamin and Feigenbaum, Joan. "Delegation Logic: A Logic-based Approach to Distributed Authorization". Forthcoming, ACM Trans. on Information Systems Security (TISSEC) journal.

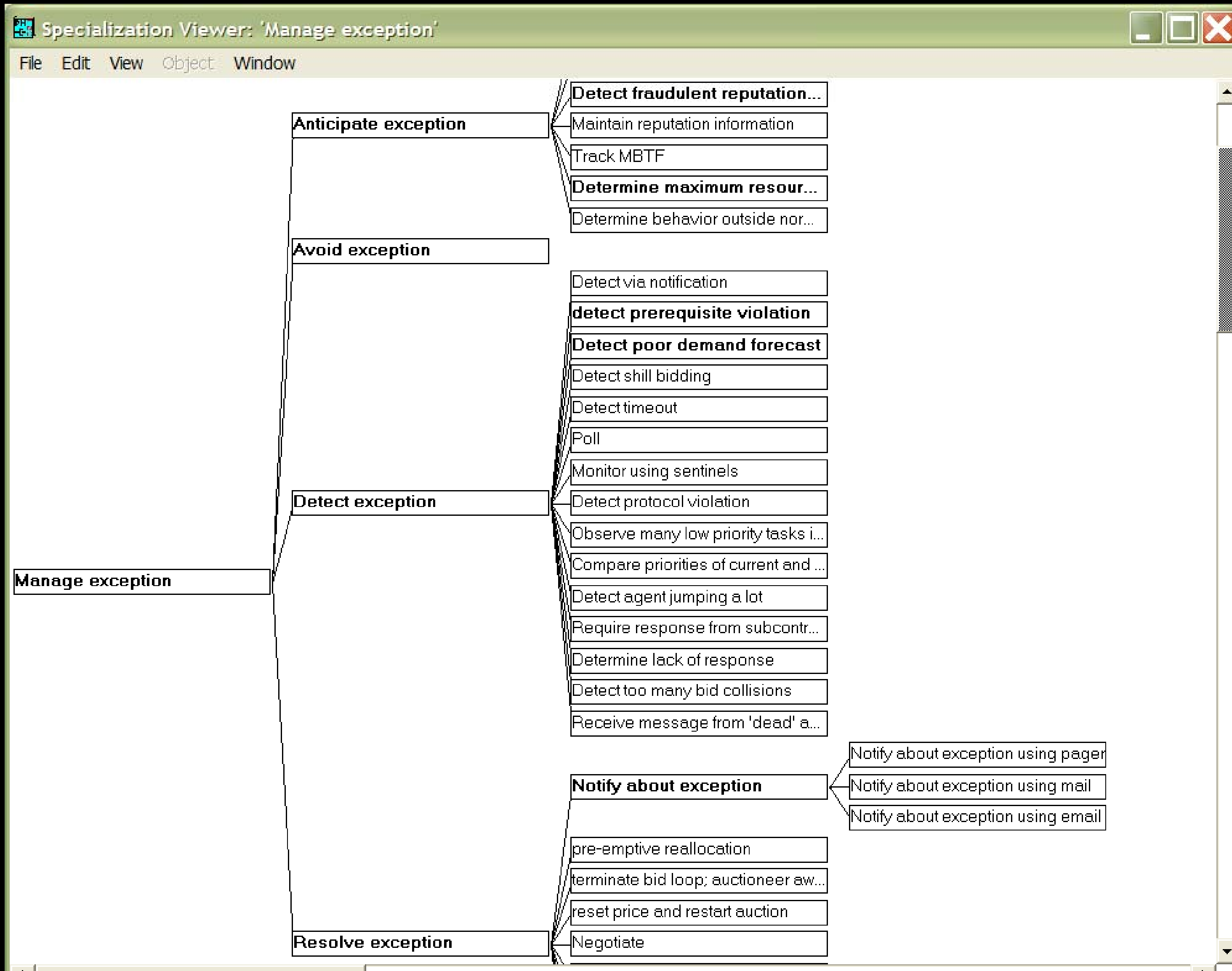
- Thanks!
- Questions?
- Comments?   Pointers?
- For More Info:
  - http://www.mit.edu/~bgrosof/

OPTIONAL SLIDES FOLLOW

Some Specializations of "Sell" in the MIT Process Handbook (PH)



Some exception handlers in the MIT Process Handbook



 by Benjamin Grosof

Translating a Rule from (Daml)RuleML to Jess

```
<damlRuleML:imp>
   <damlRuleML:_rlab>
      <damlRuleML:ind>steadySpender</damlRuleML:ind>
   </damlRuleML:_rlab>
   <damlRuleML:_body>
     <damlRuleML:andb>
        <damlRuleML:atom>
           <damlRuleML:_opr>
              <damlRuleML:rel>shopper<damlRuleML:rel>
           </damlRuleML:_opr>
           <damlRuleML:var>Cust</damlRuleML:var>
        </damlRuleML:atom>
        <damlRuleML:atom>
          <damlRuleML:_opr>
             <damlRuleML:rel>spendingHistory<damlRuleML:rel>
          </damlRuleML:_opr>
          <damlRuleML:tup>
            <damlRuleML:var>Cust</damlRuleML:var>
            <damlRuleML:ind>loyal</damlRuleML:ind>
          </damlRuleML:tup>
        </damlRuleML:atom>
      </damlRuleML:andb>
    </damlRuleML:_body>
```


Continued: Translating a Rule from (Daml)RuleML to Jess

```
<damlRuleML:_head>
    <damlRuleML:atom>
      <damlRuleML:_opr>
        <damlRuleML:rel>giveDiscount<damlRuleML:rel>
      </damlRuleML:_opr>
      <damlRuleML:tup>
       <damlRuleML:ind>percent5</damlRuleML:ind>
       <damlRuleML:var>Cust</damlRuleML:var>
      </damlRuleML:tup>
    </damlRuleML:atom>
   </damlRuleML:_head>
  </damlRuleML:imp>
```

Equivalent in JESS:

```
(defrule steadySpender
    (shopper ?Cust)
    (spendingHistory ?Cust loyal)
    =>
    (assert (giveDiscount percent5 ?Cust) ) )
```


Translating an Effector Statement

```
<damlRuleML:effe>
  <damlRuleML:_opr>
   <damlRuleML:rel>giveDiscount</damlRuleML:rel>
  </damlRuleML:_opr>
  <damlRuleML:_aproc>
   <damlRuleML:jproc>
     <damlRuleML:meth>setCustomerDiscount</damlRuleML:meth>
     <damlRuleML:clas>orderMgmt.dynamicPricing</damlRuleML:clas>
     <damlRuleML:path>com.widgetsRUs.orderMgmt
       </damlRuleML:path>
   </damlRuleML:jproc>
  </damlRuleML:_aproc>

</damlRuleML:effe>
```

Associates with predicate P : an attached procedure A that is side-effectful.

- Drawing a conclusion about P triggers an action performed by A.

jproc = Java attached procedure.

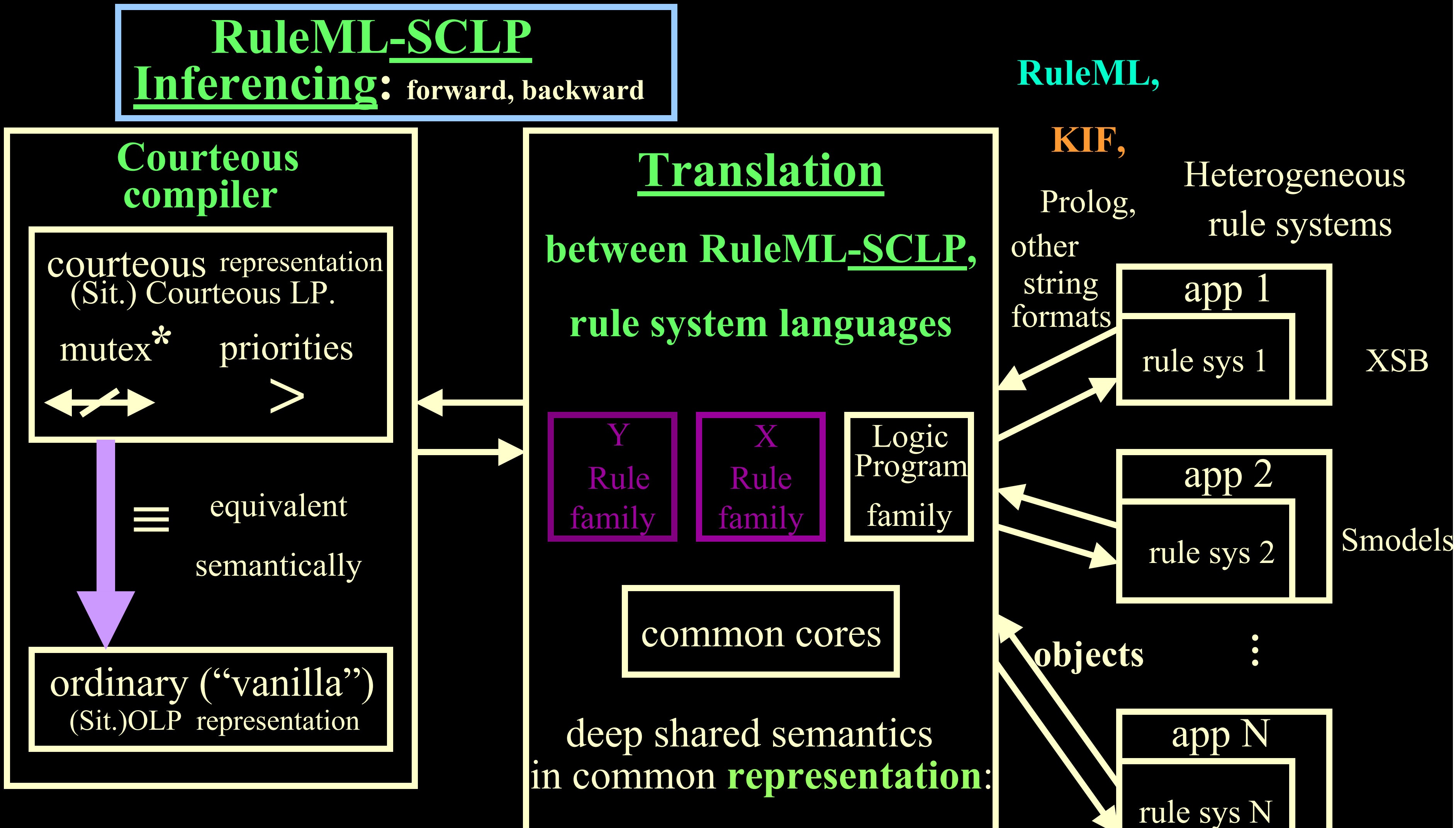
meth, clas, path = its methodname, classname, pathname.

Equivalent in JESS: key portion is:

```
(defrule effect_giveDiscount_1
  (giveDiscount ?percentage ?customer)
  =>
  (effector setCustomerDiscount orderMgmt.dynamicPricing
                  (create$ ?percentage  ?customer) ) )
```

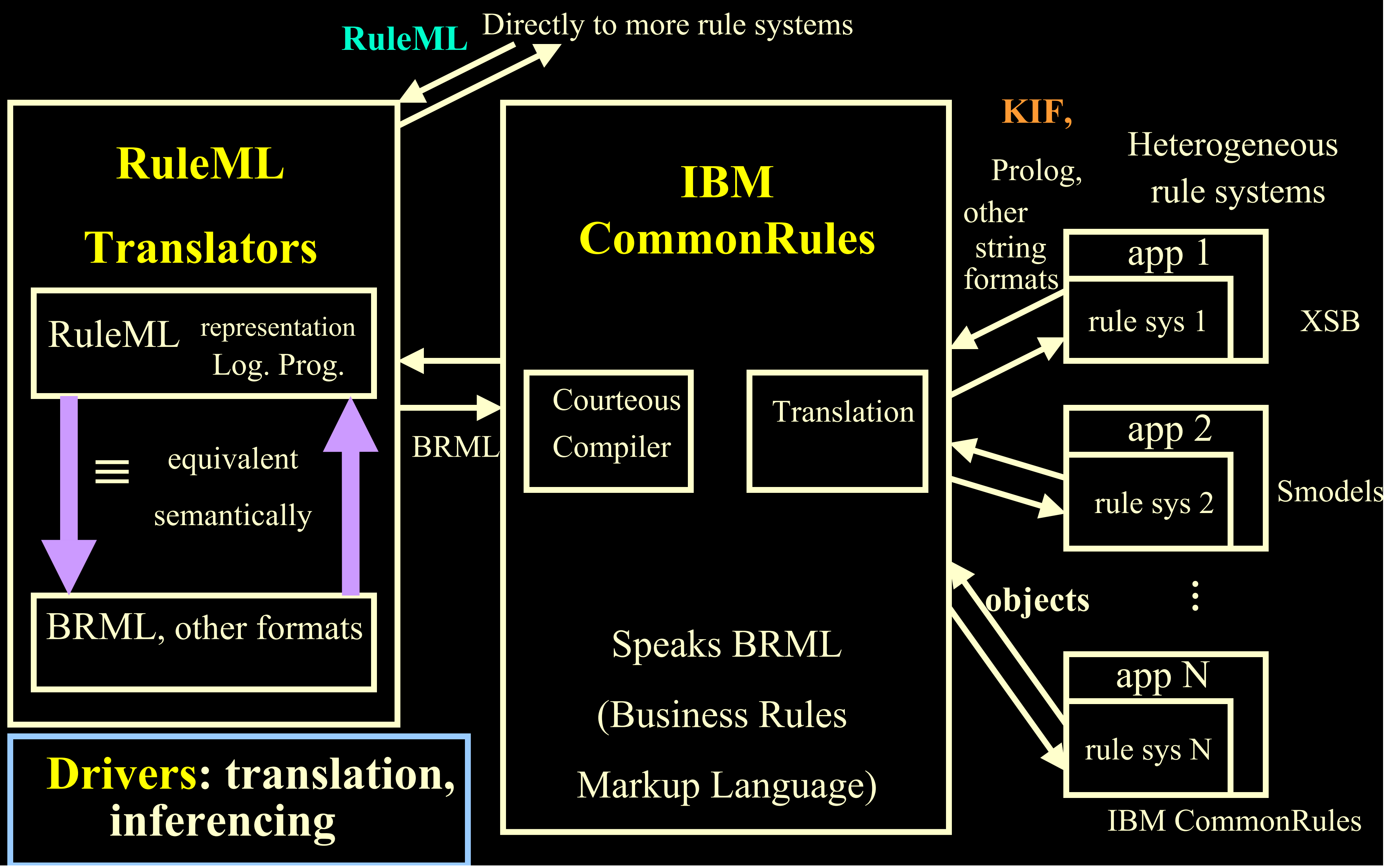
Functionality: SWEETRules Prototype

(Semantic WEb Enabling Technology)



* classical negation too

Dec.-2001 Architecture: SWEETRules Prototype
(Semantic WEb Enabling Technology)



Speaker Bio

- Benjamin Grosof is Douglas Drane Assistant Professor in Information Technology at MIT Sloan School of Management. His research is to create and study knowledge-based information technology for e-commerc eapplications, including high-level business/agent communication,information integration, contracts/negotiation, trust, product descriptions, business rules/policies, Web services, and e-marketplaces. The pioneer of inter-operable XML business rules and of their application to contracting, he co-leads the RuleML emerging industry standards effort on inter-operable XML/RDF rules. He is PI currently for a project in the DARPA Agent Markup Language (DAML) initiative, to create Semantic Web technology and explore its business applications.

- Previously, he was a senior research scientist at IBM T.J. Watson Research Center (12 years there), where most recently he conceived and led IBM CommonRules (V3.0 currently on IBM alphaWorks) and co-led its application piloting for rule-based XML agent contracting in EECOMS, a $29Million NIST industry consortium project on manufacturing supply chain management. His notable technical contributions also include fundamental advances in rule-based security authorization, conflict handling for rules, rule-based intelligent agents, and integration of rules with machine learning. He is author of over 30 refereed publications, two major software releases, and a patent. His recent service includes co-chairing the AAAI (National Conference on Artificial Intelligence) Workshops on AI in E-Commerce (1999) and Knowledge-Based E-Markets (2000). His background includes 2 years in software startups, PhD in Computer Science (specialty AI) from Stanford University, and BA in Applied Mathematics from Harvard University.

