SweetRules:
Tools for RuleML Inferencing and Translation

Benjamin Grosof

MIT Sloan School of Management

Information Technologies group

http://ebusiness.mit.edu/bgrosof

Slides of invited presentation at Developers Day, Rules on the Web track, at 13th International Conference on the World Wide Web (WWW-2004), New York, NY, USA, May 22, 2004 http://www.www2004.org

Outline

- Concept, Architecture, and Goals
- Rule and Ontology Languages/Systems involved
- Capabilities and Components Today
- More about Combining Rules with Ontologies
- Application Scenarios and Examples
- Status and Plans
- Motivations, revisited: Conclusions and Directions
- Acknowledgements
- Resources

Context and Players

- Part of SWEET = "Semantic WEb Enabling Tools" (2001 –)
  - Other parts:
    - SweetDeal for e-contracting
      - Which uses SweetRules

- Cross-institutional. Collaborators invited!
  - Originated and coordinated by MIT since 2001
  - Code by MIT, UMBC, U. Karlsruhe, U. Zurich
  - Uses code by IBM, SUNY Stonybrook, Sandia Natl. Labs, Helsinki
  - More loosely, several other institutions cooperating: BBN, NRC/UNB, Stanford
  - Many more are good targets: subsets of Flora, cwm, Triple, Hoolet, ?Jena, DRS, ?ROWL, KAON (main), JTP, SWI Prolog, ...

Concept, Architecture, and Goals

- Concept and Architecture: Tools suite for Rules and RuleML
  - Translation and interoperability between heterogeneous rule systems (forward- and backward-chaining) and their rule languages/representations
  - Inferencing including via translation between rule systems
  - Authoring and testing of rulebases
  - Open, lightweight, extensible, pluggable architecture overall

- Goals:
  - Research vehicle: embody ideas, implement application scenarios (e.g., contracting, policies)
    - Situated Courteous Logic Programs (SCLP) KR
    - Description Logic Programs (DLP) KR which is a subset of SCLP KR
  - Proof of concept for feasibility, including of translations between heterogenous families of rule systems
    - Encourage others: researchers; industry esp. vendors

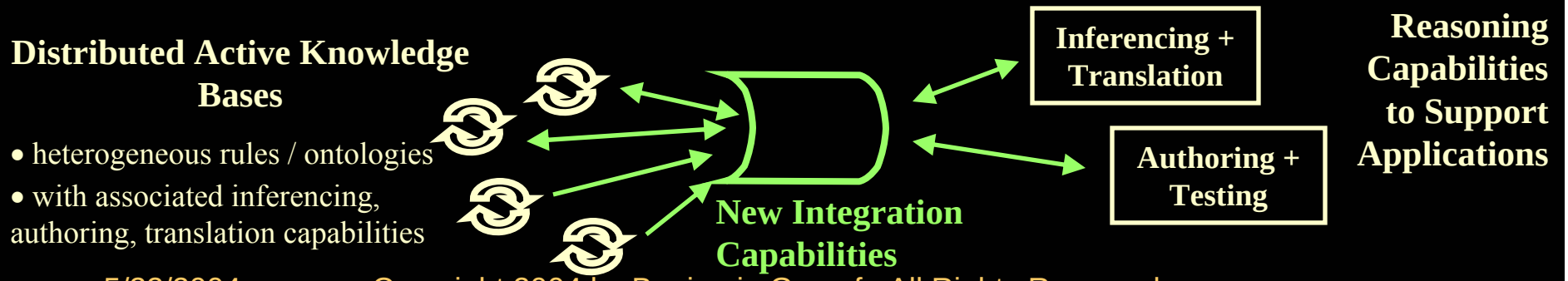
SweetRules Overview

Key Ideas:

- Unite the commercially most important kinds of rule and ontology languages via a a new, common knowledge representation (SCLP) in a new standardized syntax (RuleML), including to cope with *heterogeneity* and resolve contradictory *conflicts*.
  - Capture most of the useful expressiveness, interoperably and scalably.
- Combine a large *distributed* set of rule and ontology knowledge bases that each are *active:* each has a different *associated engine* for reasoning capabilities (inferencing, authoring, and/or translation).
- Based on recent fundamental KR theory advances, esp. Situated Courteous Logic Programs (SCLP) and Description Logic Programs.
  - Plus semantics-preserving translations between different rule languages/systems/families

Application Areas (prototyped scenarios):

- Policies and authorizations; contracting, supply chain management; retailing, customer relationship management; business process automation and e-services; financial reporting and information; etc.



RuleML KR Expressiveness

- SweetRules supports: RuleML in its highly expressive Situated Courteous Logic Programs (SCLP) extension, V0.8
  - Horn LP …
  - + Negation-As-Failure = "Ordinary" LP (OLP)
  - + Courteous feature: prioritized conflict handling (partially ordered priorities, mutual exclusion integrity constraints, e.g., for partial-functionality; limited classical negation of atoms, e.g., p vs. not-p in heads)
  - + Situated feature: procedural attachments
    - Sensors: external queries when rule body atoms are tested
      - Built-ins in SWRL V0.6 correspond to sensors.
    - Effectors: external actions triggered when rule head atoms are concluded
- RuleML also supports *referencing* OWL/DAML+OIL ontologies
    - URI predicate name (in RuleML rule) refers to class or property (in OWL axioms)
  - This was pioneered in SweetDeal using SweetRules
  - The same approach was then taken in SWRL V0.5+

Rule and Ontology Languages/Systems That Interoperate via SweetRules and RuleML, Today

1. RuleML
   - SCLP extension, V0.8
2. XSB (the pure subset of it = whole Ordinary LP)
   - Backward. Prolog. Fast, scalable, popular. Good support of SQL DB's (e.g., Oracle) via ODBC backend. Full well-founded-semantics for OLP. Implemented in C. By SUNY Stonybrook. Open source on sourceforge. Well documented and supported. Papers.
3. Jess (a pure subset of it = a large subset of Situated Ordinary LP)
   - Forward. Production Rules (OPS5 heritage). Flexible, fast, popular. Implemented in Java. By Sandia National Labs. Semi-open source, free for research use. Well documented and supported. Book.
   - *Uses recent novel theory for translation between SOLP and Production Rules.*
4. IBM CommonRules (whole = large subset of stratified SCLP)
   - Forward. SCLP. Implemented in Java. Expressive. By IBM Research. Free trial license, on IBM AlphaWorks (since 1999). Considerable documentation. Papers. Piloted.
   - Implements the Courteous Compiler (CC) KR technique.
     - which reduces (S)CLP to equivalent (S)OLP, tractably.
   - Includes bidirectional translators for XSB, KIF, Smodels.
   - Its overall concept and design was point of departure for several aspects of SweetRules

Rule and Ontology Languages/Systems That Interoperate via SweetRules and RuleML, Today, continued

5. Knowledge Interchange Format (KIF) (a subset of it = an extension of Horn LP)
   - First Order Logic (FOL). Semi-standard, morphing into Simple Common Logic ISO standard. Several tools support, e.g., JTP. Research language to date.
     - Note: FOL is superset of DLP and of SWRL's fundamental KR.
6. OWL (the Description Logic Programs subset)
   - Description Logic ontologies. W3C standard. Several tools support, e.g., FACT, RACER, Jena, Hoolet, etc.
   - *Uses recent novel DLP theory for translation between Description Logic and Horn LP.*
7. Process Handbook (large subset = subset of SCLP)
   - Frame-style object-oriented ontologies for business processes design, i.e., for services descriptions. By MIT and Phios Corp. (spinoff). Large (5000 business processes). Practical, commercial. Good GUI. Open source license in progress. Available free for research use upon request. Includes extensive textual information too. Well documented and supported. Papers. Book. Dozens of research users.
   - *Uses recent novel SCLP representation of Frames with multiple default inheritance.*
8. Smodels (NB: somewhat old version; large subset = finite OLP)
   - Forward. Ordinary LP. Full well-founded-semantics or stable semantics. Implemented in C. By Helsinki univ. Open source. Research system.

Capabilities and Components Today

- Translators in and out of RuleML:
  - RuleML ↔ {XSB, Jess, CommonRules, KIF, Smodels}
  - RuleML ← {OWL, Process Handbook} (one-direction only)
  - SOLP RuleML ← SCLP RuleML (Courteous Compiler)
- Inferencing engines in RuleML via translation:
  - Simple drivers translate to another rule system, e.g., CommonRules, Jess, or XSB, then run inferencing in that system's engine, then translate back.
  - Observation: Can easily combine components to do other kinds of inferencing, in similar indirect style, by combining various translations and engines.
- Authoring and Testing front-end: currently rudimentary, partial
  - Command-line UI + Dashboard GUI with set of windows
  - Edit rulebases. Run translations. Run inferencing. Compare.
  - Edit in RuleML. Edit in other rule systems' syntaxes. Compare.
  - View human-oriented presentation syntax. View XML syntax. (Future: RDF.)

Capabilities and Components Today, cont.'d

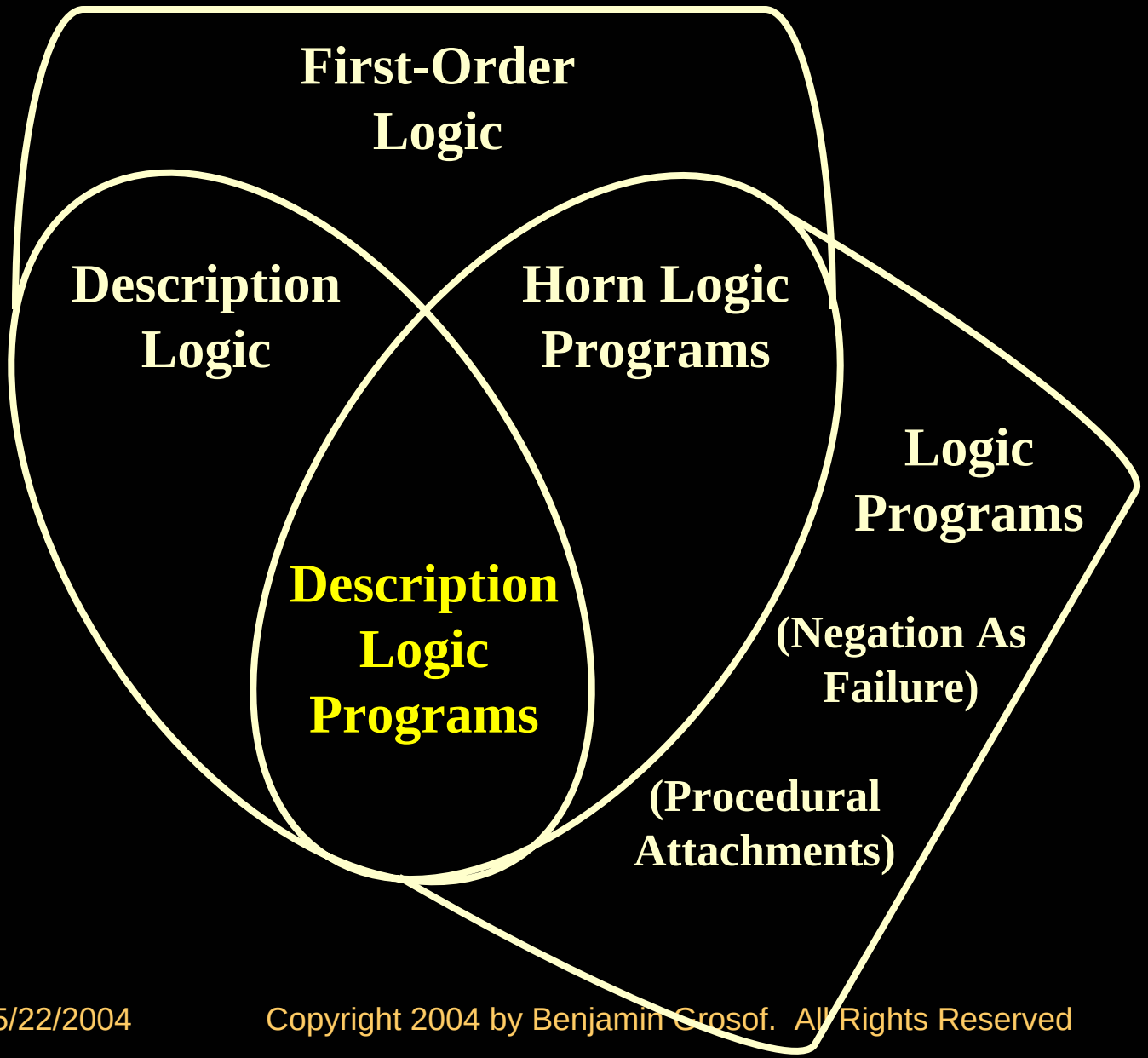
- Uses Courteous Compiler to support Courteous feature (prioritized conflict handling) even in systems that don't directly support it, as long as they support negation-as-failure
  - E.g., XSB Prolog, Jess, Smodels
  - Uses Courteous Compiler component from IBM CommonRules
- Uses IBM CommonRules translators: CommonRules ↔ {XSB, KIF, Smodels}
- Some components have distinct names (for packaging or historical reasons):
  - SweetJess translation and inferencing RuleML ↔ Jess
    - Available upon request free for research use as download.
  - SweetOnto translation RuleML ← OWL
    - Available currently as part of KAON open-source code base, called "DLP" component there
- Code base: Java, XSLT, shell scripts (for testing drivers)

More about Combining Rules with Ontologies

There are several ways to use SweetRules to combine rules with ontologies:

1. By reference: via URI as name for predicate
2. Translate DLP subset of OWL into RuleML
   - Then can add SCLP rules
     - E.g., add Horn LP rules and built-in sensors
       ⇒ interesting subset of the SWRL V0.6 KR
     - E.g., add default rules or procedural attachments
3. Translate non-OWL ontologies into RuleML
   - E.g., object-oriented style with default inheritance
     - E.g., Courteous Inheritance for Process Handbook ontologies
4. Use RuleML Rules to map between ontologies
   - E.g., in the spirit of the Extended COntext Interchange (ECOIN) approach/system.
   - SWRL V0.6 good start for mapping between non-DLP OWL ontologies.

Venn Diagram: Expressive Overlaps among KR's



Translating a Fact from RuleML to Jess

```
<damlRuleML:fact>
    <damlRuleML:_rlab>fact8962</damlRuleML:_rlab>
        <damlRuleML:_head>
          <damlRuleML:atom>
             <damlRuleML:_opr>
                <damlRuleML:rel>shopper<damlRuleML:rel>
             </damlRuleML:_opr>
             <damlRuleML:ind>Debbie</damlRuleML:ind>
          </damlRuleML:atom>
        </damlRuleML:_head>
</damlRuleML:fact>

equivalent in JESS:
  (assert (shopper Debbie) )
```

Translating a Rule from 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 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) ) )
```

Some New Research Application Scenarios for Rule-based Semantic Web Services

- SweetDeal [Grosof & Poon WWW-2003] configurable reusable e-contracts:
  - Represents modular modification of proposals, service provisions
    - LP rules as KR. E.g., prices, late delivery exception handling.
    - On top of DL ontologies about business processes from MIT Process Handbook
  - Evolved from EECOMS pilot on agent-based manufacturing SCM
    ($51M NIST ATP 1996-2000 IBM, Boeing, TRW, Vitria, others)
- Financial knowledge integration (ECOIN) [Firat, Madnick, & Grosof 2002]
  - Maps between contexts using LP rules, equational ontologies, SQL DB's.
- Business Policies:
  - Trust management (Delegation Logic) [Li, Grosof, & Feigenbaum 2003]: Extend LP KR to multi-agent delegation. Ex.: security authorization.

Status and Plans

- Downloadable currently:
  - SweetJess
  - SweetOnto = KAON's DLP component
- Rest of suite is currently being updated to support:
  - latest versions of RuleML and CommonRules
  - hosting on open-source site (plan: on semwebcentral.org)
- Recent project emphasis overall on papers and specifications.

- Planned: part of new phase of DAML Rules tools effort
  - Generally polish, integrate
  - Collaborators: Said Tabet, RuleML; Mike Dean, BBN; Mark Musen, Stanford; Harold Boley, NRC/UNB

Status and Plans, continued

- Additional Goals:
  - More meat to pluggable architecture
  - More authoring/UI capabilities
  - More SWRL support
  - More wrt additional kinds of rule systems:
    - ECA rules, SQL (needs some theory work, e.g., events for ECA)
    - RDF-Query and XQuery
  - More wrt connections-to / support-of web services:
    - Importing knowledge bases / modules, procedural attachments, translation/inferencing, events, …
  - Explore applications in services, e.g., policies, contracts
- More Collaborators Invited!
  - Many more rule/ontology systems are good targets for interoperation/translation:
    - Flora, cwm, Triple, Hoolet, Jena, DRS, ROWL, KAON, JTP, SWI Prolog, …

Flavors of Rules Commercially Most Important today in E-Business

- E.g., in OO app's, DB's, workflows.

- Relational databases, SQL: Views, queries, facts are all rules.
- Production rules (OPS5 heritage): e.g.,
  - Jess, CLIPS, ILOG, Blaze, Haley: rule-based Java/C++ objects.
- Event-Condition-Action rules (loose family), cf.:
  - business process automation / workflow tools.
  - active databases; publish-subscribe.
- Prolog. *"logic programs" as a full programming language.*
- *(Lesser: other knowledge-based systems.)*

Summary of Objectives Motivating SweetRules: Integrating Distributed Rules and Ontologies

Address "the 5 D's" of real-world reasoning ⇒ *desired improvements*:

1. **D**iversity – Existing/emerging kinds of ontologies and rules have heterogeneous KR's. *Handle more heterogeneous systems.*
2. **D**istributedness - of ownership/control of ontology/rule active KB's. *Handle more source active KB's.*
3. **D**isagreement - Conflict (contradiction) will arise when merging knowledge. *Handle more conflicts.*
4. **D**ynamism - Updates to knowledge occur frequently, overturning previous beliefs. *Handle higher rate of revisions.*
5. **D**elay - Computational scaleability is vital to achieve the promise of knowledge integration. *Achieve Polynomial-time (~ databases).*

Summary of Objectives Motivating SweetRules: Integrating Distributed Rules and Ontologies, cont.'d

BEFORE

AFTER

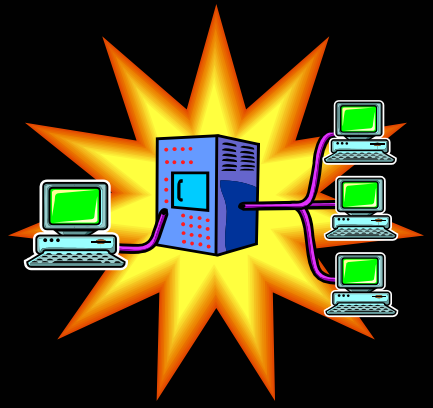
Contradictory conflict is globally contagious, invalidates all results.

⇒

Contradictory conflict is contained locally, indeed tamed to aid modularity.

Knowledge integration tackling the 5 D's (esp. diversity and distributedness) is labor-intensive, slow, costly.

⇒



Knowledge integration is highly automated, faster, cheaper.

Acknowledgements

- Many people have contributed to SweetRules
  - Can't mention everyone here
- Thanks especially to:
  - Hoi Chan, IBM (CommonRules lead implementer)
  - Terrence Poon, MIT (translators implementer)
  - Mahesh Gandhe, UMBC ⇒ IBM (SweetJess lead implementer)
  - Timothy Finin, UMBC (SweetJess)
  - Abraham Bernstein, U. Zurich (Process Handbook)
  - Boris Motik, U. Karlsruhe (SweetOnto lead implementer)
  - Earl J. Wagner, MIT (authoring lead implementer)
  - Ian Horrocks, U. Manchester (DLP theory)
  - Raphael Volz, U. Karlsruhe (DLP, SweetOnto)
  - M. Youssef Kabbaj, MIT (translators implementer)

Resources

- See papers, talk slides, and links at http://ebusiness.mit.edu/bgrosof
- ../#RecentSoftware : Links to SweetJess, SweetOnto, CommonRules (where can download)
- ../#RecentPapersByTopic : (for most below, there are earlier versions too)
  - "Representing E-Commerce Rules Via Situated Courteous Logic Programs in RuleML", *Electronic Commerce Research and Applications*, 2004.
  - "SweetDeal: Representing Agent Contracts With Exceptions using Semantic Web Rules, Ontologies, and Process Descriptions", *International Journal of Electronic Commerce*, to appear summer 2004.
  - "Description Logic Programs: Combining Logic Programs with Description Logic", WWW-2003.
  - "SweetJess: Inferencing in Situated Courteous RuleML via Translation to and from Jess Rules", 2003 working paper updating RuleML-2002 Workshop paper.
  - "A Declarative Approach to Business Rules in Contracts: Courteous Logic Programs in XML", EC-99.
  - "Beyond Monotonic Inheritance: Towards Semantic Web Process Ontologies", 2003.
  - "SWRL: A Semantic Web Rules Language Combining OWL and RuleML", 2004.
- RuleML http://www.ruleml.org
- DAML Rules http://www.daml.org/rules
- Joint Committee http://www.daml.org/committee
- SemWebCentral http://www.semwebcentral.org

Outline

- Concept, Architecture, and Goals
- Rule and Ontology Languages/Systems involved
- Capabilities and Components Today
- More about Combining Rules with Ontologies
- Application Scenarios and Examples
- Status and Plans
- Motivations, revisited: Conclusions and Directions
- Acknowledgements
- Resources

OPTIONAL SLIDES FOLLOW

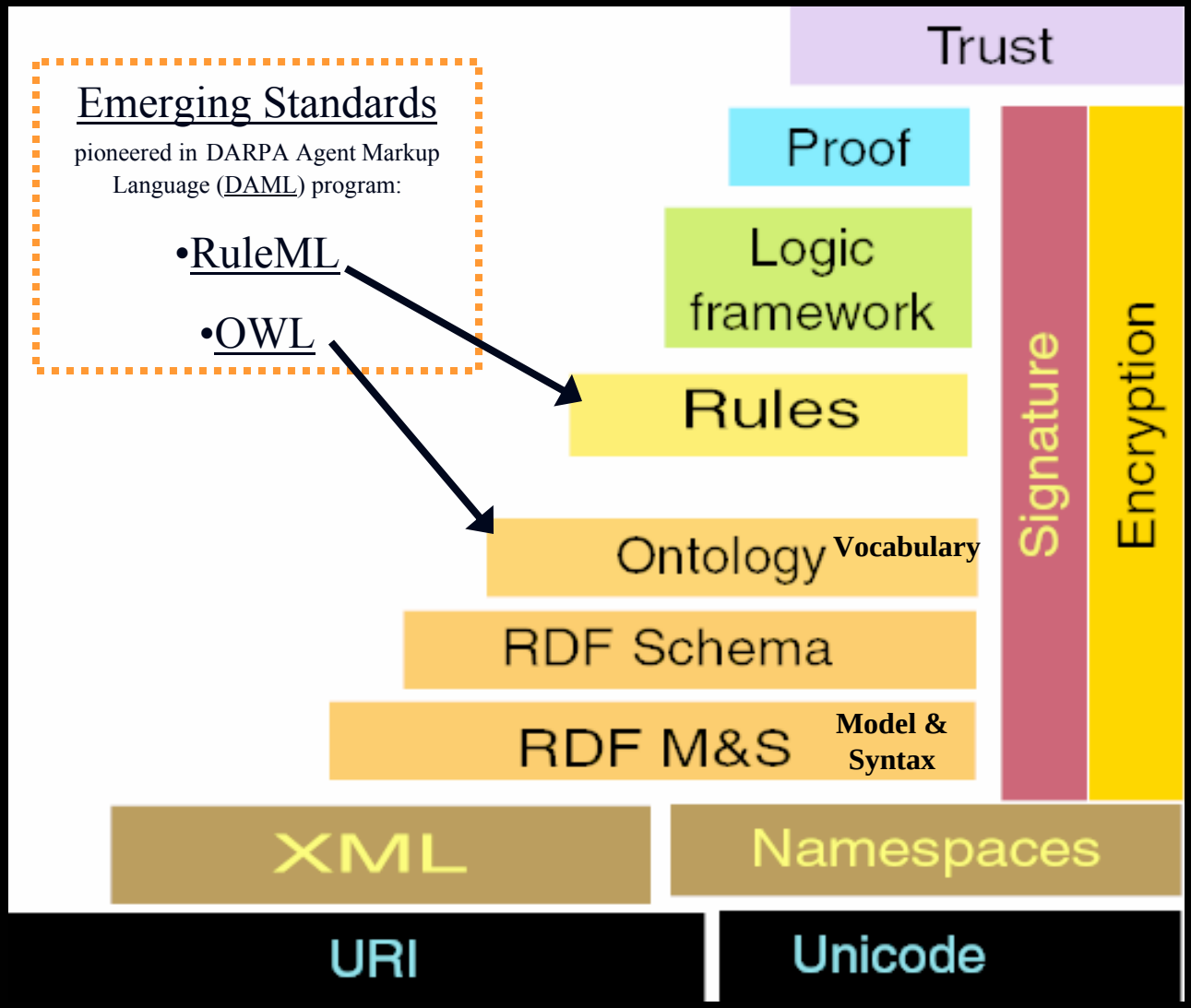
Quickie Bio of Presenter

- MIT Sloan professor since 2000
- 12 years at IBM T.J. Watson Research; 2 years at startups
- PhD Comp Sci, Stanford; BA Applied Math Econ/Mgmt, Harvard
- Semantic web services is main research area:
  - Rules as core technology
  - Business Applications, Implications, Strategy:
    - e-contracting/supply-chain; finance; trust; …
  - Overall knowledge representation, e-commerce, intelligent agents
- Co-Founder, Rule Markup Language Initiative – the leading emerging standards body in semantic web rules (http://www.ruleml.org)
- Core participant in Semantic Web Services Initiative – which coordinates world-wide SWS research and early standards (http://www.swsi.org)
  - Area Editor for Contracts & Negotiation, Language Committee
  - Co-Chair, Industrial Partners program (SWSIP)

3 Areas of New Fundamental KR Theory
that enable Key Technical Requirements for SWS

- 1. Description Logic Programs: [Grosof, Horrocks, Decker, & Volz WWW-2003]
  KR to combine LP (RuleML) rules on top of DL (OWL) ontologies, with:
  - Power in inferencing (including for consistency)
  - Scaleability of inferencing
- 2. Situated Logic Programs: [Grosof et al 1995; Grosof et al. 2002; Grosof ECRA 2004]
  KR to hook rules (with ontologies) up to (web) services
  - Rules use services, e.g., to query, message, act with side-effects
  - Rules constitute services executably, e.g., workflow-y business processes
- 3. Courteous Logic Programs: [Grosof ILPS-97; Grosof, Labrou, & Chan EC-99]
  KR to combine rules from many sources, with:
  - Prioritized conflict handling to enable consistency, modularity; scaleably
  - Interoperable syntax and semantics
  - Well represents default inheritance in process ontologies (*courteous inheritance*)
- *RuleML includes support for (1.)-(3.).*

W3C Semantic Web "Stack": Standardization Steps



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

Vision: Uses of Rules in E-Business

- Rules as an important aspect of coming world of Internet e-business: rule-based business policies & business processes, for B2B & B2C.
  - represent seller's offerings of products & services, capabilities, bids; map offerings from multiple suppliers to common catalog.
  - represent buyer's requests, interests, bids; → matchmaking.
  - represent sales help, customer help, procurement, authorization/trust, brokering, workflow.
  - high level of conceptual abstraction; easier for non-programmers to understand, specify, dynamically modify & merge.
  - executable but can treat as data, separate from code
    - potentially ubiquitous; already wide: e.g., SQL views, queries.
- Rules in communicating applications, e.g., embedded intelligent agents.

SweetDeal Approach: Rule-based Contracts for E-commerce

[Grosof, Labrou, & Chan EC-99; Wellman, Reeves, & Grosof CI '02; Grosof & Poon IJEC '04]

- Rules as way to specify (part of) business processes, policies, products: as (part of) contract terms.
  - Combined with ontologies.
- Complete or partial contract.
  - As default rules. Update, e.g., in negotiation. Exceptions handling.
- Rules provide high level of conceptual abstraction.
  - easier for non-programmers to understand, specify, dynamically modify & merge. E.g.,
  - by multiple authors, cross-enterprise, cross-application.
- Executable. Integrate with other rule-based business processes.
- SWEET = Semantic WEb Enabling Technology
  - software components, theory, approach
  - pilot application scenarios, incl. contracting (SweetDeal)

Examples of Contract Provisions Well-Represented by Rules in Automated Deal Making

- Product descriptions
  - Product catalogs: properties, conditional on other properties.
- Pricing dependent upon: delivery-date, quantity, group memberships, umbrella contract provisions
- Terms & conditions: refund/cancellation timelines/deposits, lateness/quality penalties, ordering lead time, shipping, creditworthiness, biz-partner qualification, service provisions
- Trust
  - Creditworthiness, authorization, required signatures
- *Buyer Requirements (RFQ, RFP) wrt the above*
- *Seller Capabilities (Sourcing, Qualification) wrt the above*

Where Rules Shine in Goals wrt Key SWS Tasks

- Knowledge reuse in knowledge-based service descriptions:
  - … Across the Key Tasks in our Requirements:
    - Contracts (proposals, request-for-proposals, selection, negotiation, advertising); Discovery; Enactment, Composition; Monitoring, Problem resolution, Exception handling; Verification
    - Business/Trust/Security/Privacy Policies
    - Semantic Interoperability (mappings, specializations)
    - Underlying: Hypothetical Reasoning

Where are the Holdups? … and Challenges for Research

- KR & standards to integrate Rules with Ontologies more expressively
- KR, & later standards, to represent Services descriptions using Rules and Ontologies.
  - A step is our SweetDeal approach; much current work in SWSI.
- KR & strategy to leverage legacy content, e.g., OO service/process ontologies
  - A rich research area. We are doing much current work on that.
    - Preliminary-version approach is available as paper "Beyond Monotonic Inheritance: Towards Semantic Web Process Ontologies" at http://ebusiness.mit.edu/bgrosof
- Procedural process models aspect of SWS, as underlying foundation
  - Messy, many competing conceptual approaches
  - Realm of slow progress; much energy in WS standards efforts:
    - Oasis WSBPEL, W3C WS Choreography