The Thinking Internet – How the Semantic Web Will Transform Business

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URL for FINAL version of this presentation:
http://ebusiness.mit.edu/bgrosof/#MITITConf0405Talk

Quickie Bio of Presenter Benjamin Grosof

- 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)
- Area Editor, Semantic Web Services Initiative – which coordinates world-wide SWS research and early standards (http://www.swsi.org)

Resources for this Session

- This slideset
  - Some of it will only be skimmed in this presentation
  - FINAL version is at: http://ebusiness.mit.edu/bgrosof/MITITConf0405Talk
- Prof. Grosof's website (http://ebusiness.mit.edu/bgrosof)
- … see especially there:
  - Recent talks
  - ISWC-2004 Tutorial slideset
  - SweetRules toolset (http://sweetrules.projects.semwebcentral.org)

Outline of Session

- Intro: What is the Semantic Web
  - Knowledge Representation in XML; Agents; with Web Services
- Why it Matters for Business
  - Knowledge-based Services Engineering
  - Examples of Policies for Contracting and Authorization
    - Pricing, Comparison Shopping, Ordering Lead Time, …
- Semantic Rules: Technology and Standardization
  - RuleML, Theory Advances, SweetRules Open Source Platform
- Roadmapping Business Value and Market Evolution
  - Cheaper, Faster, Better; EAI and B2B; Early Verticals

Talk Mode: the MIT Firehose

Shortened from a 90-minute talk
⇒ Some skimmed

Exploding Research Interest in SW

Since 2002: …

- International Semantic Web Conference (ISWC) formed
  - Grown to 400+ researchers
- Became 2nd largest topic area of the International Conference on the World Wide Web (WWW)
  - (1st is Search, i.e., Google etc.)
- Specialized conferences formed: e.g., RuleML
- Major Research Programs in US and EU
- Professional Societies Chapters formed: e.g., AIS SIG
- Journals formed: e.g., J. Web Semantics
- Several industry standards efforts (some done)

The Semantic Web

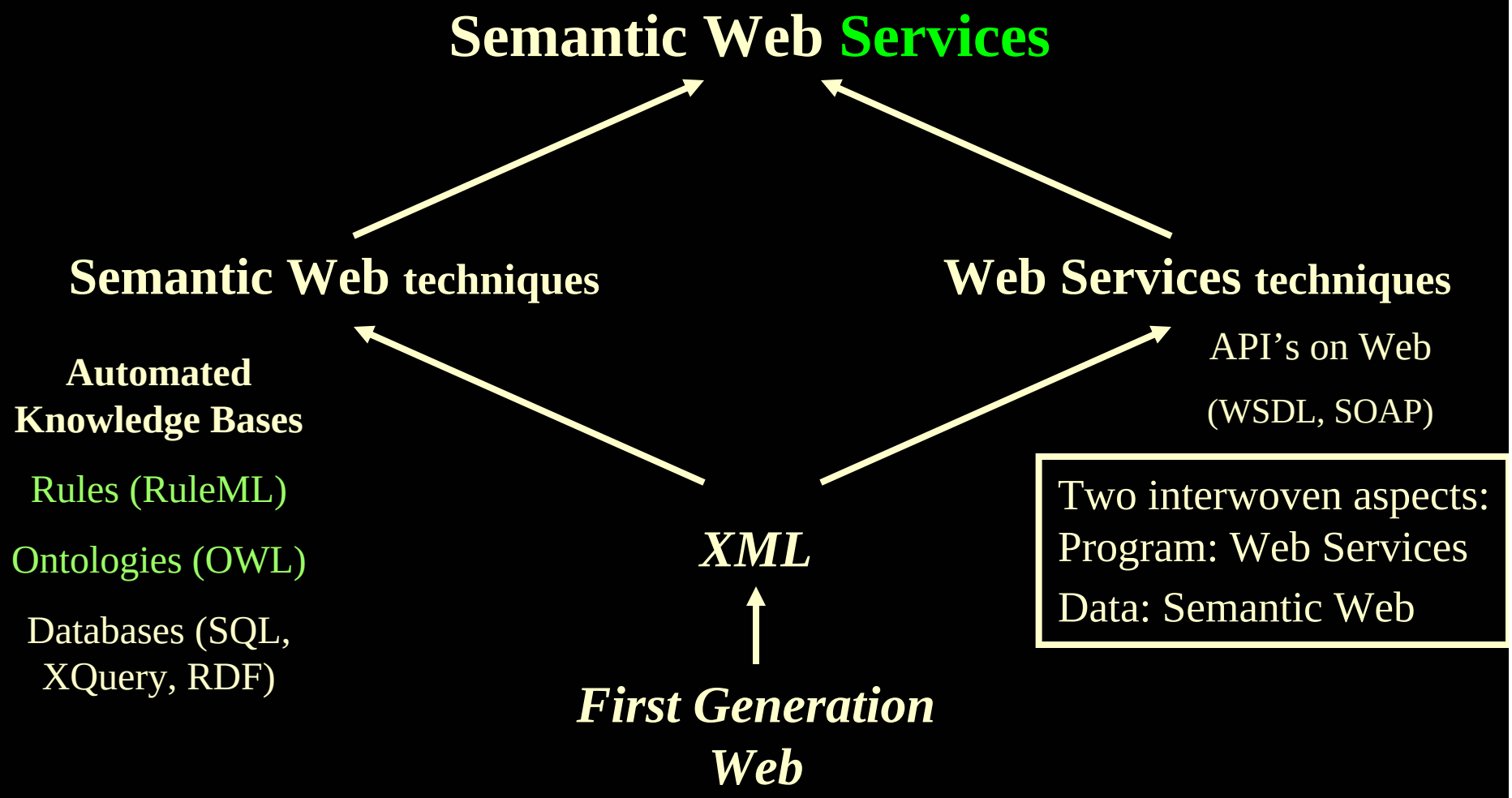
- The 1st generation, the Internet, enabled disparate machines to exchange data.
- The 2nd generation, the World Wide Web, enabled new applications on top of the growing Internet, making enormous amounts of information available, in human-readable form, and allowing a revolution in new applications, environments, and B2C e-commerce.

- The next generation of the net is an "agent-enabled" resource (the "Semantic Web") which makes a huge amount of information available in machine-readable form creating a revolution in new applications, environments, and B2B e-commerce.

…by enabling "agent" communication at a Web-wide scale.

  - "Agent" = knowledge-based application

Next Generation Web



Two interwoven aspects:
Program: Web Services
Data: Semantic Web

Vision of Evolution: Agents in Knowledge-Based E-Markets

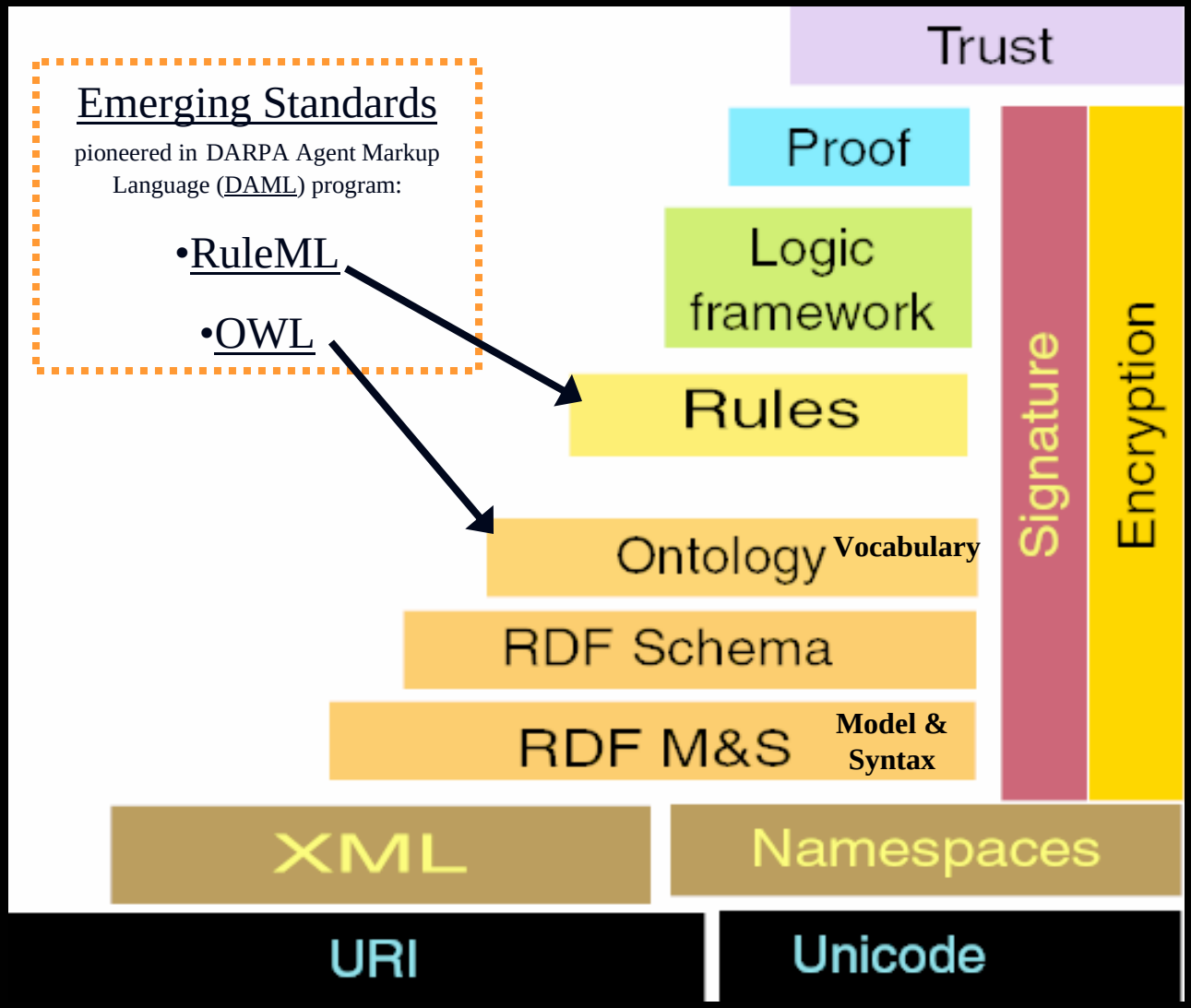
Coming soon to a world near you:...

- billions/trillions of agents (= k-b applications)
- ...with smarts: knowledge gathering, reasoning, economic optimization
- ...doing our bidding
  - but with some autonomy
- *A 1st step: ability to communicate with sufficiently precise shared meaning... via the SEMANTIC WEB*

Semantic Web: concept, approach, pieces

- Shared semantics when interchange data ∴ knowledge
- Knowledge Representation (cf. AI, DB) as approach to semantics
  - Standardize KR syntax, with KR theory/techniques as backing
- Web-exposed Databases: SQL; XQuery (XML-data DB's)
  - Challenge: share DB schemas via meta-data
- RDF: "Resource Description Framework" W3C standard
  - Meta-data lower-level mechanics: unordered directed graphs (vs. ordered trees)
  - RDF-Schema extension: simple class/property hierarchy, domains/ranges
- Ontology = formally defined vocabulary & class hierarchy
  - OWL: "Ontologies Working Language" W3C standard
    - Subsumes RDF-Schema and Entity-Relationship models
    - Based on Description Logic (DL) KR ~subset of First-Order Logic (FOL))
- Rules = if-then logical implications, facts ~subsumes SQL DB's
  - RuleML: "Rule Markup Language" emerging standard
    - Based on Logic Programs (LP) KR ~extension of Horn FOL
    - Also provide FOL KR

W3C Semantic Web "Stack": Standardization Steps



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

SW Stack: Acronym Expansion

- W3C = World Wide Web Consortium: umbrella standards body
- XML-S: XML Schema, i.e., basic XML spec
- RDF: Resource Description Framework:
  - W3C Working Group
  - Labelled directed graph syntax
  - Good for building knowledge representation on top of: simpler, more powerful than basic XML
  - M&S = Model and Syntax
  - RDF Schema = extension: simple class hierarchies
- Ontology = formally defined vocabulary & class hierarchy, generalizes Entity-Relationship models
  - OWL = W3C Web Ontologies Working Language
  - … based closely on DAML+OIL

SW Overall Dependencies

- The W3C “stack” picture is a rough simplification.
- Rules do not require RDF
  - Can just use XML or even an ASCII “presentation syntax”
- Ontologies do not require RDF nor OWL
  - There are other techniques; OWL lacks some features
    - OWL does require RDF
- Customers and major vendors will be still digesting XML data management in next 2-5 years
  - … before moving on to heavy RDF usage

Concept of Knowledge Representation (KR)

- A knowledge representation S is defined as a triple (LP, LC, |=), where:
  - LP is a formal language of sets of premises (i.e., premise expressions)
  - LC is a formal language of sets of conclusions (i.e., conclusion expressions)
  - |= is the entailment relation.
    - Conc(P,S) stands for the set of conclusions that are entailed in KR S by a set of premises P
    - We assume here that |= is a functional relation.

Example of Entailment: Mortality

- In First-Order Logic (FOL) KR:
  - Let P be the premises:
  - $\forall$?X. human(?X) $\Rightarrow$ mortal(?X).
  - human(Socrates).
  -
  - In FOL, P entails (among others) the conclusion:
    - mortal(Socrates).
  - Notation:
    - "$\forall$" means "for all".
    - "?" Prefixes a logical variable.

Example of Entailment: Sunday Stroll

- In Bayesian Probability KR:
  - Let P be the premises:
    - prob(rainySunday) = 0.4.
    - prob(funSunday | rainySunday) = 0.3.
    - prob(funSunday | ¬rainySunday) = 0.9.
  -
  - In this KR, P entails (among others) the conclusion:
    - prob(funSunday) = 0.66.

Example of Entailment: Discounting

- In the Courteous Logic Programs KR (e.g., RuleML):

  Let P be the premises:

  – {loyald} discount(?cust, RamadaHotel, 10percent)
  ← memberOf(?cust, AAA).

  – {seniord} discount(?cust, RamadaHotel, 25percent)
  ← age(?cust, ?x) and greaterThan(?x, 64).

KR: What's the Game? Desiderata

- Expressiveness: what can be said
  - useful, natural, complex enough
- Syntax: encoding data format -- e.g., in XML
  - easy enough to edit and communicate, by computers and by humans
- Semantics: principles of sanctioned inference, independent of reasoning algorithms:
  - clear, useful, natural, and understandable enough
- Computational Tractability (esp. worst-case): scale up in a manner qualitatively similar to relational databases: computation cycles go up as a polynomial function of input size
- Reasoning algorithms (compute the entailed conclusions):
  - sound (correct), complete, efficient, clear, and simple enough to engineer

MIT Leadership Roles in SW

1. Prof. Benjamin Grosof at MIT Sloan
   - Rules theory, tools, standards
   - Business implications: e-contracting, finance, security/trust
     - Policies, Rule-based SW Services
     - Applications, Roadmaps, Strategy
   - Co-lead RuleML Initiative, main emerging standards effort in SW Rules
   - Evangelism, esp. to Business & Business Schools
   - MIT Sloan Team: Prof. Stuart Madnick, Dr. Michael Siegel, others

2. Tim Berners-Lee at W3C & MIT CSAIL
   - Overall SW vision, standards
   - Evangelism, esp. on RDF
   - Experimental tools, incl. RDF rules, applications
   - MIT CSAIL Team: Eric Miller, Sandro Hawke, Lalana Kagal, others

- Above (1.)+(2.) Collaborating esp. on Rules, Standards, Policies, Evangelism

Our Research Aspects/Questions about the Semantic Web

- Core technologies: Requirements, concepts, theory, algorithms, standards?
  - Rules in combination with ontologies; probabilistic, decision-/game-theoretic

- Business applications and implications: concepts, requirements analysis, techniques, scenarios, prototypes; strategies, business models, market-level evolution?
  - End-to-end e-contracting, finance, trust; …

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Some Answers to: "Why does SW Matter to Business?"

- 1. "Death. Taxes. Integration." - They're always with us.
- 2. "Business processes require communication between organizations / applications." - Data and programs cross org./app. boundaries, both intra- and inter- enterprise.
- 3. "It's the *automated knowledge* economy, stupid!" - The world is moving towards a knowledge economy. And it's moving towards deeper and broader automation of business processes. The first step is automating the use of structured knowledge.
  - Theme: *reuse* of knowledge across multiple tasks/app's/org's

Strategic Business Foci in our SW Research

- Knowledge-based Services Engineering: intra- and inter- enterprise
- Target "killer app" known for 30 years: do better job of EDI
- Challenges:
  - Ease of development, deployment ↑
  - Reuse of knowledge ↑
  - ⇒ life cycle costs ↓, agility ↑
- Starting with: Policies
  - Using recent theory breakthroughs in semantic rules
  - E.g., for end-to-end contracting and authorization (incl. security)
- Starting with: EAI as well as B2B

SW Rules: Use Cases from our research

- Contracts/negotiation, advertising/discovery
  - E-procurement, E-selling
  - Pricing, terms & conditions, supplier qualification, …
- Monitoring:
  - Exception handling, e.g., of contract violations
    - Late delivery, refunds, cancellation, notifications
  - Notifications, personal messaging, and other workflow
- Trust Policies: authorization, confidentiality & privacy, security, access control
  - E.g., financial services, health care
    - *Extensive analysis of business case/value*
- Semantic mediation: rule-based ontology translation, context-based information integration

EECOMS Example of SCM Policy Rules: Ordering Lead Time

- Vendor's rules that prescribe how buyer must place or modify an order:
- A) 14 days ahead if the buyer is a qualified customer.
- B) 30 days ahead if the ordered item is a minor part.
- C) 2 days ahead if the ordered item's item-type is backlogged at the vendor, the order is a modification to reduce the quantity of the item, and the buyer is a qualified customer.

- Suppose more than one of the above applies to the current order? **Conflict!**

- Helpful Approach: **precedence** between the rules. Often only *partial* order of precedence is justified. E.g., C > A.

Courteous LP's: Ordering Lead Time Example

{leadTimeRule1} orderModificationNotice(?Order,14days)
← preferredCustomerOf(?Buyer,?Seller) ∧
purchaseOrder(?Order,?Buyer,?Seller) .

{leadTimeRule2} orderModificationNotice(?Order,30days)
← minorPart(?Buyer,?Seller,?Order) ∧
purchaseOrder(?Order,?Buyer,?Seller) .

{leadTimeRule3} orderModificationNotice(?Order,2days)
← preferredCustomerOf(?Buyer,?Seller) ∧
orderModificationType(?Order,reduce) ∧
orderItemIsInBacklog(?Order) ∧
purchaseOrder(?Order,?Buyer,?Seller) .

overrides(leadTimeRule3 , leadTimeRule1) .

⊥ ← orderModificationNotice(?Order,?X) ∧
orderModificationNotice(?Order,?Y) | (?X ≠?Y) .

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XBRL stands for eXtensible Business Reporting Language. It is or a family of "XML" languages which is becoming a standard means communicating information between businesses and on the intern

XBRL is being developed by an international non-profit consortiun approximately 250 major companies, organisations and governm agencies. **It is an open standard, free of licence fees.** It is already being put to practical use in a number of countries and implementations of XBRL are growing rapidly around the world.

This site provides information about the nature, uses and benefits XBRL. It explains how individuals and companies can join the effo move forward and make use of the language.

Equational Ontological Conflicts

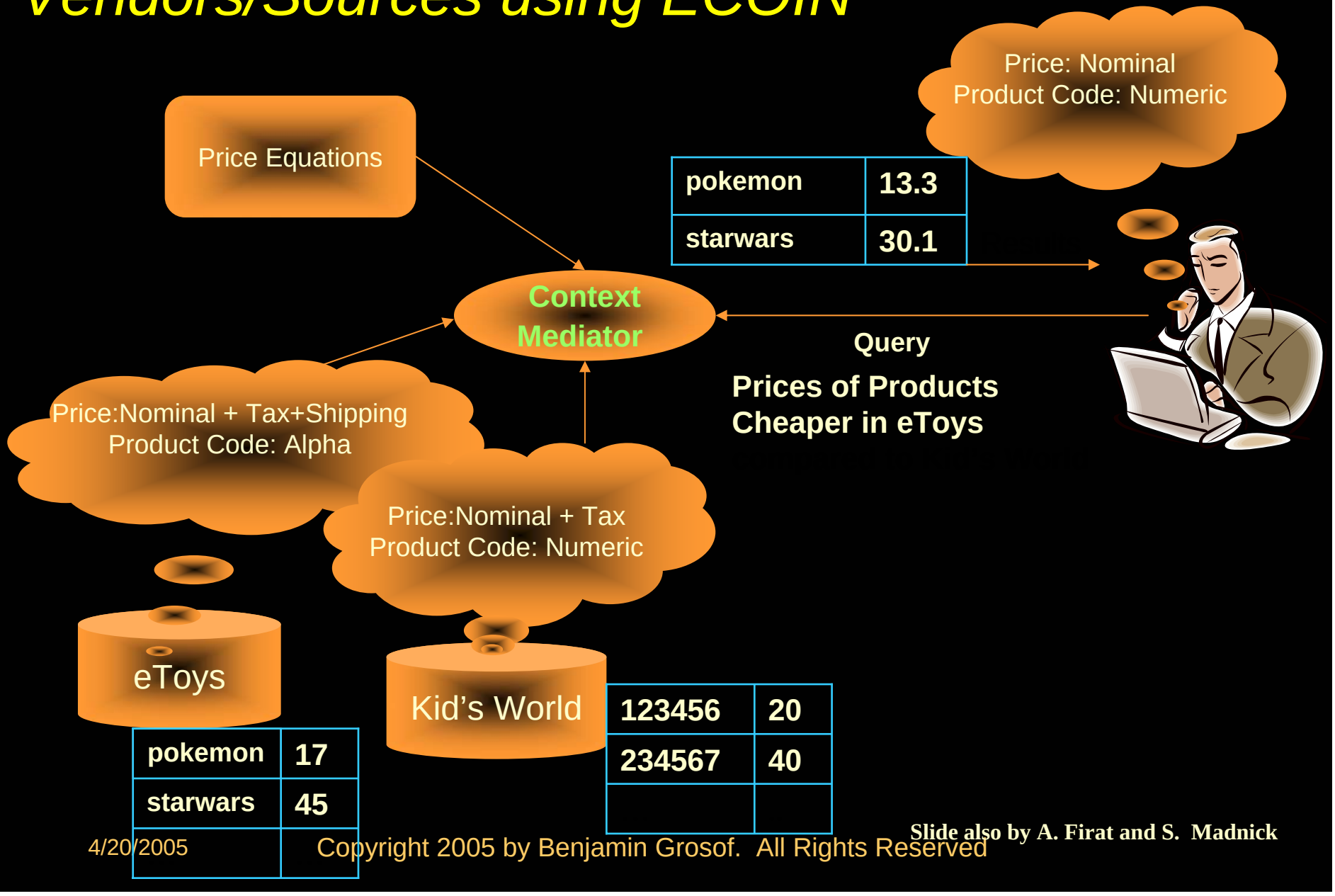
Key Concepts

Gross Profit = Net Sales – Cost of Goods	Gross Profit = Net Sales – Cost of Goods – Depreciation
Price = Nominal Price + Shipping	Price = Nominal Price + Shipping + Tax

" heterogeneity in the way data items are *calculated* from other data items *in terms of definitional equations*"

Slide also by A. Firat and S. Madnick

Comparing Prices From Multiple Vendors/Sources using ECOIN



Slide also by A. Firat and S. Madnick

Approach: ECOIN

- Extended COntext INterchange, developed at MIT Sloan
  - *[Firat, Madnick, & Grosof] (Best Paper Award WITS-2002)*
- Context-based loosely-coupled integration
  - *Extends the Context Interchange (COIN) framework also developed at MIT*
- Symbolic Equation Solving using Constraint Logic Programming
  - *Integrates symbolic equation solving techniques with abductive logic programming*
- *In-progress:* Utilizing RuleML and OWL in ECOIN

Slide also by A. Firat and S. Madnick

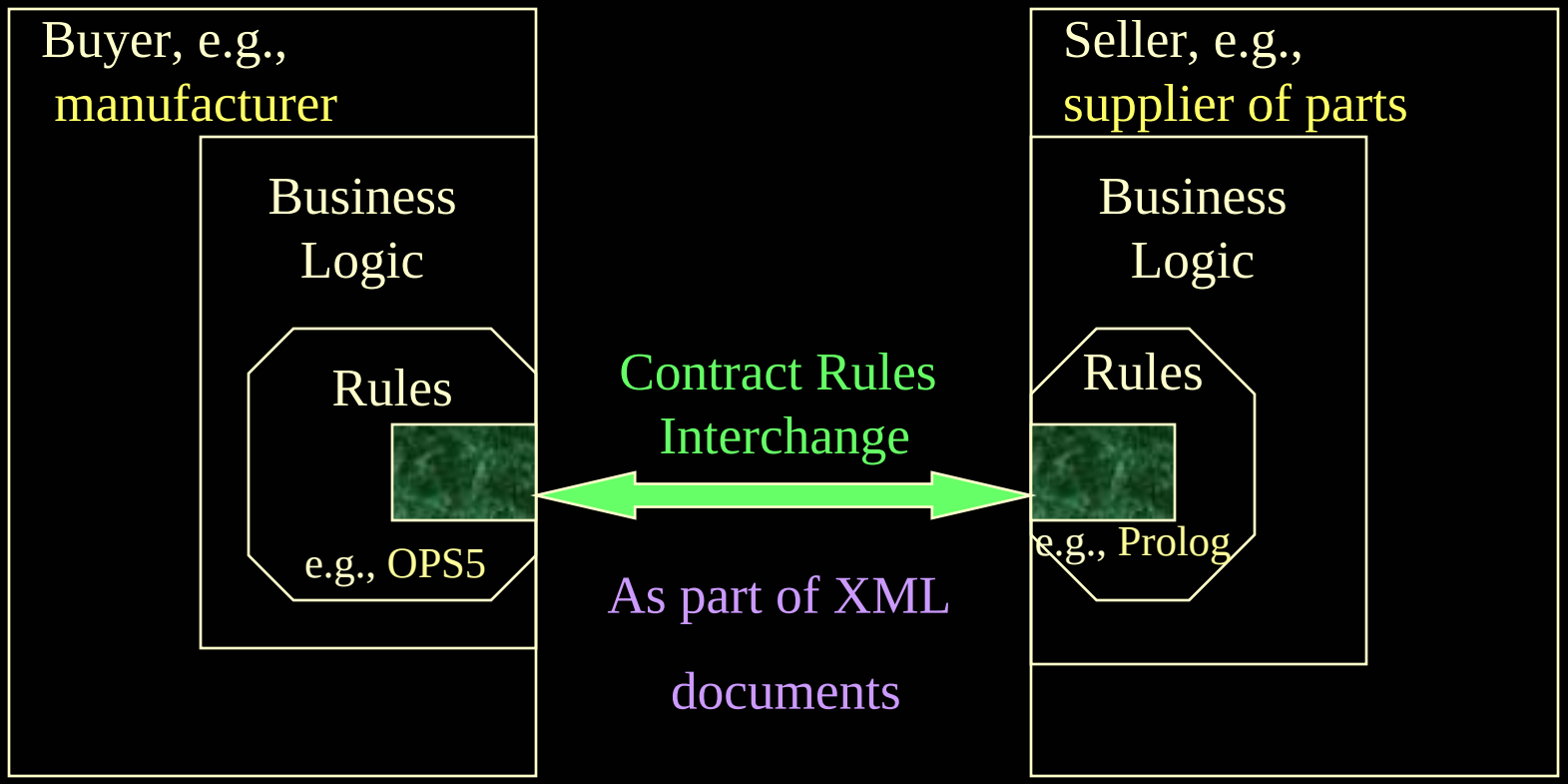
End-to-End E-Contracting Tasks

- Discovery, advertising, matchmaking
  - Search, sourcing, qualification/credit checking
- Negotiation, bargaining, auctions, selection, forming agreements, committing
  - Hypothetical reasoning, what-if'ing, valuation
- Performance/execution of agreement
  - Delivery, payment, shipping, receiving, notification
- Problem Resolution, Monitoring
  - Exception handling

SweetDeal Approach: Rule-based Contracts for E-commerce

- Rules as way to specify (part of) business processes, policies, products: as (part of) contract terms.
- Complete or partial contract.
  - As default rules. Update, e.g., in negotiation.
- 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.

Contract Rules during Negotiation

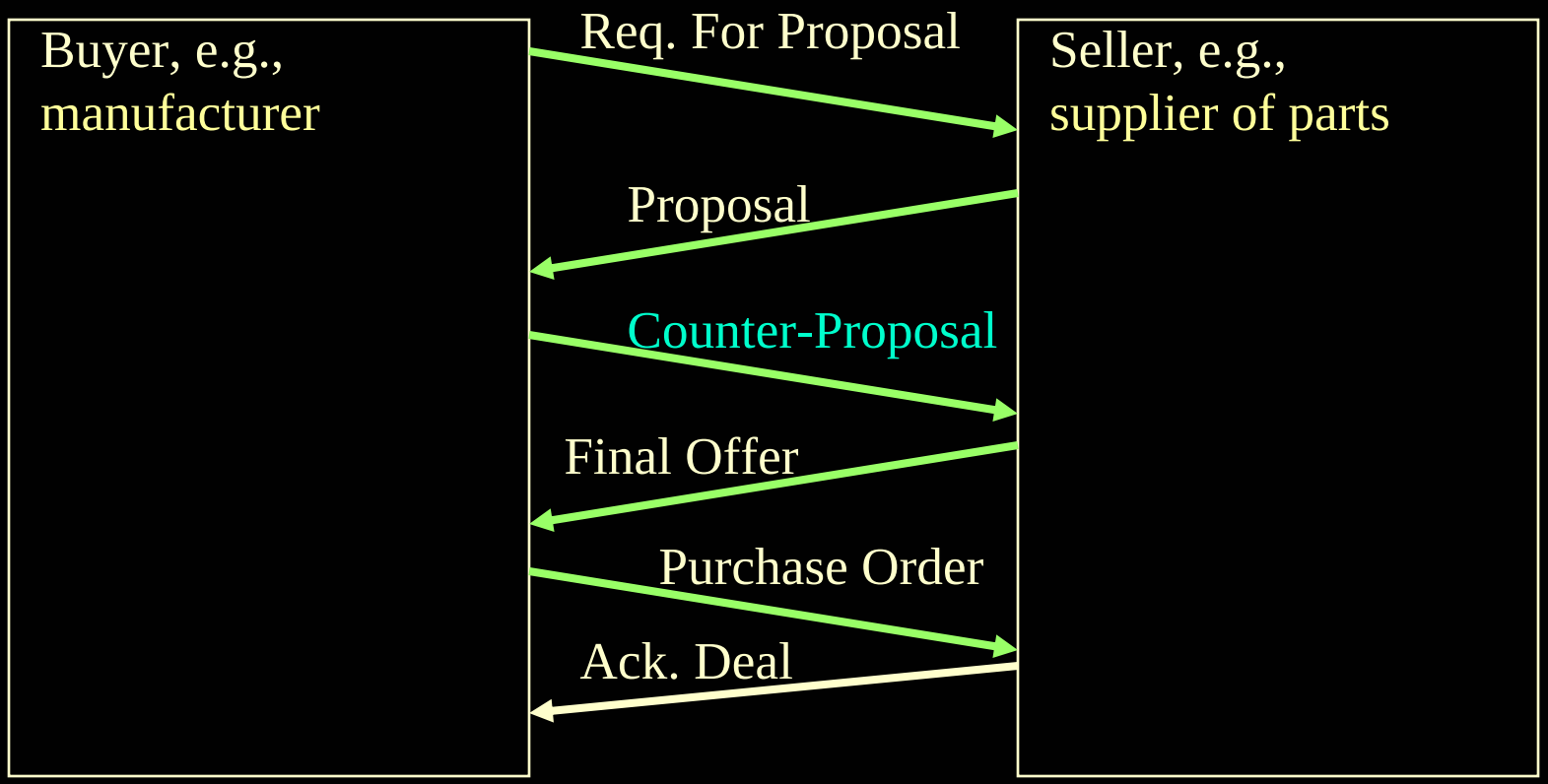


Contracting parties NEGOTIATE via shared rules.

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*

Exchange of Rules Content during Negotiation: example



Example: E-Contract Proposal from supplierCo to manufCo

- …
  {usualPrice} price(per_unit, ?PO, $60) ←
- purchaseOrder(?PO, supplierCo, ?AnyBuyer) ∧
- quantity_ordered(?PO, ?Q) ∧ (?Q ≥ 5) ∧ (?Q ≤ 1000) ∧
- shipping_date(?PO, ?D) ∧ (?D ≥ 24Apr00) ∧ (?D ≤ 12May00).
- {volumeDiscount} price(per_unit, ?PO, $51) ←
- purchaseOrder(?PO, supplierCo, ?AnyBuyer) ∧
- quantity_ordered(?PO, ?Q) ∧ (?Q ≥ 100) ∧ (?Q ≤ 1000) ∧
- shipping_date(?PO, ?D) ∧ (?D ≥ 28Apr00) ∧ (?D ≤ 12May00) .
  overrides(volumeDiscount , usualPrice) .
- ⊥ ← price(per_unit, ?PO, ?X) ∧ price(per_unit, ?PO, ?Y) GIVEN (?X ≠ ?Y).
- ...

Negotiation Ex. Doc. Rules: Counter-Proposal *from manufCo to supplierCo*

- …
  {usualPrice} price(per_unit, ?PO, $60) ← ...
- {volumeDiscount} price(per_unit, ?PO, $51) ←
- purchaseOrder(?PO, supplierCo, ?AnyBuyer) ∧
- quantity_ordered(?PO, ?Q) ∧ (?Q ≥ 5) ∧ (?Q ≤ 1000) ∧
- shipping_date(?PO, ?D) ∧ (?D ≥ 28Apr00) ∧ (?D ≤ 12May00) .
  overrides(volumeDiscount , usualPrice) .
- ⊥ ← price(per_unit, ?PO, ?X) ∧ price(per_unit, ?PO, ?Y) GIVEN (?X ≠ ?Y).
- {aSpecialDeal} price(per_unit, ?PO, $48) ←
- purchaseOrder(?PO, supplierCo, manufCo) ∧
- quantity_ordered(?PO, ?Q) ∧ (?Q ≥ 400) ∧ (?Q ≤ 1000) ∧
- shipping_date(?PO, ?D) ∧ (?D ≥ 02May00) ∧ (?D ≤ 12May00) .
- overrides(aSpecialDeal, volumeDiscount) .
- overrides(aSpecialDeal , usualPrice) .
- ...

Simply *added* rules!

Negotiation Example --

XML Encoding of Rules in RuleML

```
<rulebase>
 <imp>
  <rlab>usualPrice</_rlab>
  <head>
   <atom>
    <opr><rel>price</rel></_opr>
     <ind>per_unit</ind>
     <var>PO</var>
     <ind>$60</ind>
   </atom>
  </head>
  <body>   …  (see next page)   </_body>
 </imp>
…
</rulebase>
```

SweetDeal V2 Demo Outline

- SweetDeal E-Contracting Application using SweetRules (supply chain)
  - SCLP RuleML that includes OWL ontologies
  - Contract proposals/final-agreements are SCLP RuleML rulebases that reference/include OWL ontologies
  - Humans edit & communicate, supported by automated agents
  - Proposal evaluation supported by inferencing
  - Agreed business process is executable via inferencing+action

What Can Be Done with the Rules in contracting, & negotiation, based on our SweetDeal approach to rule representation

- Communicate: with deep shared semantics
  - via RuleML, inter-operable with same sanctioned inferences
  - ⇔ heterogeneous rule/DB systems / rule-based applications (“agents”)
- Execute contract provisions:
  - infer; ebiz actions; authorize; ...
- Modify easily: contingent provisions
  - default rules; modularity; exceptions, overriding
- Reason about the contract/proposal
  - hypotheticals, test, evaluate; tractably
  - *(also need “solo” decision making/support by each agent)*

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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.
- Known advantages of rules vs. general code
  - separable business logic, more reusable across app.'s, life cycle
  - good for loose coupling cf. workflow
  - good for representing contingent behavior of services/processes.
  - 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.

Overview of RuleML Today I

- RuleML Initiative (2000--) http://www.ruleml.org
  - Dozens of institutions (~35), researchers; esp. in US+Canada, EU
- Mission priorities:
  1. Enable semantic exchange of rules/facts between most commercially important rule systems
     - Production rules, relational databases, Prolog, Event-Condition-Action rules
  2. Synergize with RDF, OWL (& other relevant web standards as arrive)
  3. Enable rule-based semantic web services, e.g., policies
- Standards specification: current version V0.8+
  - 1st version 2001; basic now fairly stable
- Logical Knowledge Representation at core of semantics
  - Declarative Logic Programs (LP) & First Order Logic (FOL) … Webized
  - Firm foundations in decades of R&D theory, algorithms, implementations

Overview of RuleML Today II

- A number of tools (~60 engines, translators, editors), demo applications. E.g., SweetRules open source platform.
- Very influential & lots of mindshare in cutting edge R&D community. 20,000+ Google Hits (as of Mar. 2004)
- Annual International Scientific Workshop since 2002
- Cooperating closely with the leading umbrella Web standards organizations and SW research efforts:
  - OMG – providing markup and semantics for production rules meta-model.
  - Discussions well underway to launch Oasis, W3C standards working groups.
  - Encouraged (and funded in part) by DARPA
  - Collaborating with Semantic Web Services Initiative (SWSL), Web Services Mediation Language (WSML) & REWERSE in EU

Semantic Rules: Differences from Rules in the 1980's / Expert Systems Era

- Get the KR right
  - More mature research understanding
  - Semantics independent of algorithm/implementation
  - Cleaner; avoid general programming/scripting language capabilities
  - Highly scaleable; high performance; better algorithms
  - Highly modular wrt updating; use prioritization
- Leverage Web, esp. XML
  - Interoperable syntax
  - Merge knowledge bases
- Embeddable
  - Into mainstream software development environments (Java, C++, C#); not its own programming language/system (cf. Prolog)
- Knowledge Sharing: intra- or inter- enterprise
- Broader set of Applications

New Fundamental Rule KR Theory
that enables Key Technical Requirements for SWS

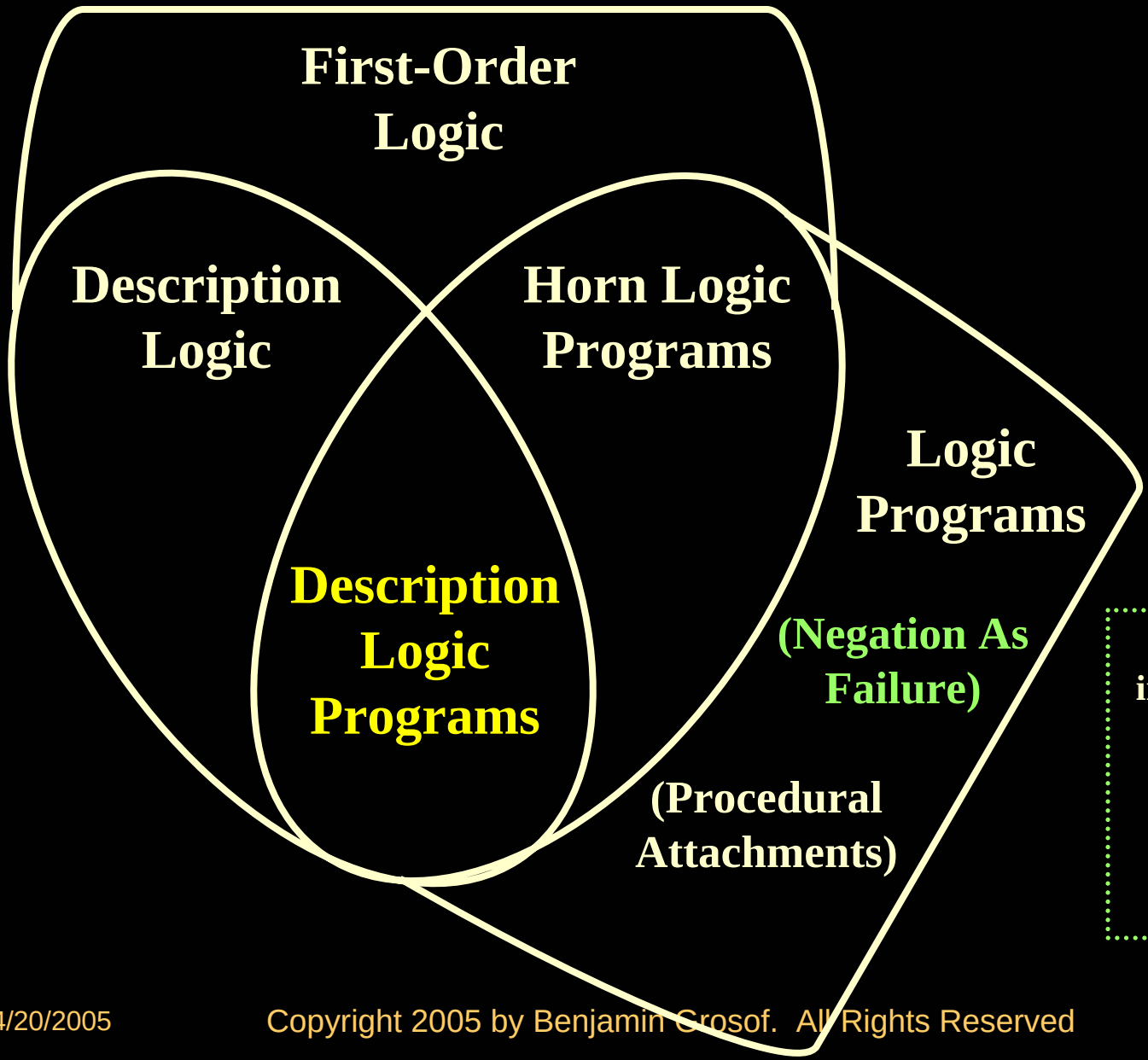
In 1985-94:

- Prolog interoperable with relational DB; LP extends core-SQL [many]
- Richer logical connectives, quantifiers [Lloyd & Topor]
- "Well Founded" Semantics for Negation-As-Failure [Van Gelder et al; Przmusinski]
- Hilog quasi-higher order expressiveness, meta-syntax flexibility [Kifer et al.]
- Frame syntax cf. F-Logic [Kifer *et al.*]

In 1995-2004:

- Courteous LP: prioritized conflict handling [Grosof]
  - Robust, tractable, modular merging & updating
- Situated LP: hook rules up to services [Grosof]
- Description LP: combine Description Logic ontologies [Grosof *et al.*]
- Courteous Inheritance: combine OO default ontologies [Grosof *et al.*]
- Production Rules as LP: interoperate [Grosof *et al.*]
  - Declarative LP as interoperable core between commercial families [Grosof *et al.*]
- Hypermonotonic Reasoning: combine with FOL [Grosof (in-progress)]

Venn Diagram: Expressive Overlaps among KR's



NB: Nonmon LP, including Courteous, relies on NAF as fundamental underlying KR expressive mechanism

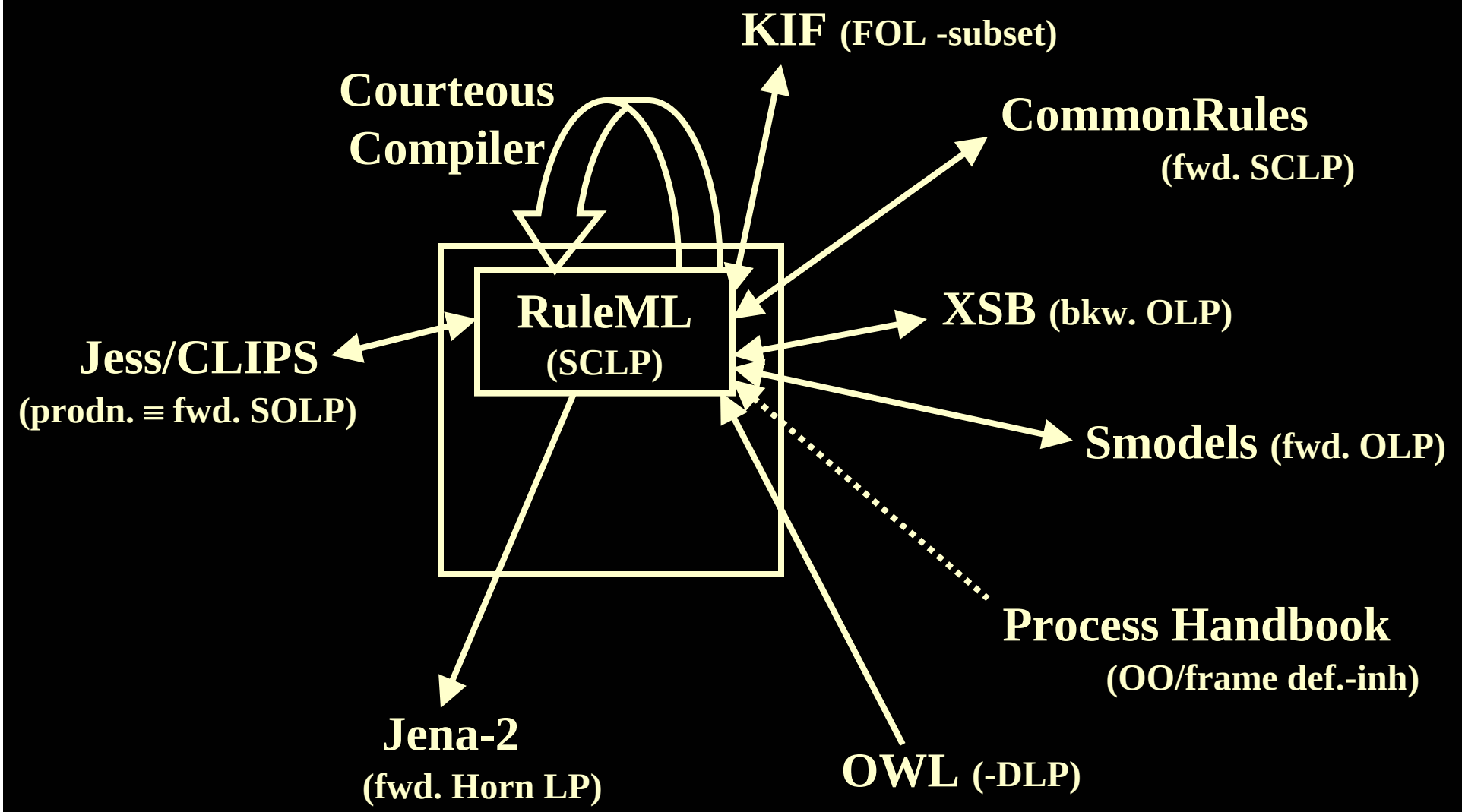
SweetRules Overview

- Concept and Architecture: Open Source Tools Platform for SW Rules and RuleML. http://sweetrules.projects.semwebcentral.org (2004-)
  - Multi-institutional collaboration led by MIT Sloan, with 12+ other co.'s / univ.'s
- Capabilities:
  - Translation and interoperability between heterogeneous rule systems (forward- and backward-chaining) and their rule languages/representations of the most commercially important flavors (relational database / Prolog and production rules / event-condition-action)
  - Inferencing including via translation between rule systems
  - Authoring, Analysis, and testing of rulebases
  - Open, lightweight, extensible, pluggable architecture overall
  - Merge knowledge bases
    - Combine rules with ontologies, incl. OWL, OO default inheritance
  - Focus on kinds of rule systems that are commercially important
    - E.g., Jess production rules, XSB Prolog, IBM Common Rules, HP Jena, …
  - Highly scaleable performance by piggybacking on mature commercial implementations (e.g., Jess, XSB)
  - Automatically composes translators, inference engines

SweetRules V2.0 Fundamental KR

- Fundamental KR: Situated Courteous Logic Programs (SCLP) KR = Knowledge Representation
  - Horn
  - + Negation-As-Failure (NAF) = Ordinary LP
  - + Courteous prioritized conflict handling
    - overrides relation on rule labels, classical negation, mutex integrity constraints
  - + Situated sensing & effecting
    - Invoke external procedural attachments
    - Sensing = tests/queries; e.g., built-ins
    - Effecting = side-effectful actions, triggered by conclusions

SweetRules V2.0 Translators Graph



Objectives for Integrating Distributed SW Rules and Ontologies, Motivating SweetRules and its underlying theory+standards

BEFORE

AFTER

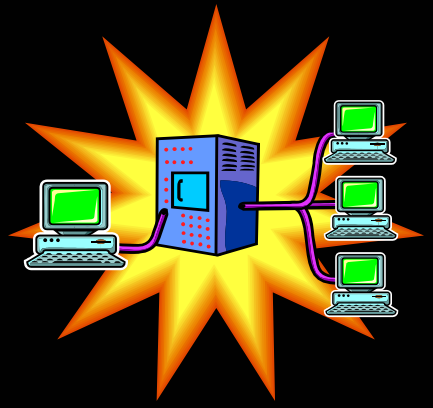
Contradictory conflict is globally contagious, invalidates all results.

⇒

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

Knowledge integration tackling the 5 D's (diversity, distributedness, disagreement, dynamism, & delay) is labor-intensive, slow, costly.

⇒



Knowledge integration is highly automated, faster, cheaper.

SweetRules: Use Cases Overview

- Contracts/negotiation, advertising/discovery
  - E-procurement, E-selling
  - Pricing, terms & conditions, supplier qualification, …
- Monitoring:
  - Exception handling, e.g., of contract violations
    - Late delivery, refunds, cancellation, notifications
  - Notifications, personal messaging, and other workflow
- Trust Policies: authorization, confidentiality & privacy, security, access control
  - E.g., financial services, health care
    - *Extensive analysis of business case/value*
- Semantic mediation: rule-based ontology translation, context-based information integration

Outline of Session

- Intro: What is the Semantic Web
  - Knowledge Representation in XML; Agents; with Web Services
- Why it Matters for Business
  - Knowledge-based Services Engineering
  - Examples of Policies for Contracting and Authorization
    - Pricing, Comparison Shopping, Ordering Lead Time, …
- Semantic Rules: Technology and Standardization
  - RuleML, Theory Advances, SweetRules Open Source Platform
- Roadmapping Business Value and Market Evolution
  - Cheaper, Faster, Better; EAI and B2B; Early Verticals

Advantages of Standardized SW Rules for Policies, e.g., Authorization/Security

- Easier Integration: with rest of business policies and applications, business partners, mergers & acquisitions
  - Enterprise integration, B2B
- Familiarity, training
- Easier to understand and modify by humansChange management
- Quality and Transparency of implementation in enforcement
  - Provable guarantees of behavior of implementation
- Reduced Vendor Lock-in
- Expressive power
  - Principled handling of conflict, negation, priorities
- $\Rightarrow$ Agility, change management $\uparrow$

Advantages of SW Rules, cont'd:
Loci of Business Value in Policy Management

- Reduced system dev./maint./training costs
- Better/faster/cheaper policy admin.
- Interoperability, flexibility and re-use benefits
- Greater visibility into enterprise policy implementation $\Rightarrow$ better compliance
- Centralized ownership and improved governance by Senior Management
- Rich, expressive policy management language allows better conflict handling in policy-driven decisions
- Strategic agility, incl. wrt business model

SWS Adoption Roadmap: Some Strategy Considerations

- "Death. Taxes. Integration."
- Expect see beginning in a lot of B2B interoperability or heterogeneous-info-integration intensive (e.g., finance, travel)
  - Actually, probably 1st intra-enterprise, e.g., EAI
- Reduce costs of communication in procurement, operations, customer service, supply chain ordering and logistics
- Agility/speed/flexibility in business processes, supply chains
- "Killer app" target known for 30 years: do better job of EDI

Prospective SW Early Adopters:
Areas by Industry or Task

- *We've discussed a number of industry or task areas:*
  - Manufacturing supply chain, procurement, pricing, selling, e-tailing, financial/business reporting, authorization/security/access/privacy policies, health records, credit checking, banking, brokerage, contracts, advertising, …
- Others:
  - travel "agency", i.e.: tickets, packages
    - See Trading Agent Competition, [M.Y. Kabbaj thesis]
  - military intelligence (e.g., funded DAML)

Some Technical Directions for Research

- Incremental Reasoning: Events, Updates
- LP KR other extensions:
  - Existentials via skolemization
  - Combine Hilog higher-order features reducible to first-order; OWL-Full, RDF-Full
  - Equality: user-defined, nonmonotonic
  - Reification
- Hypermonotonicity: analysis of LP, merging; new KR's incl. disjunctive
- Probabilistic, decision-theoretic, game-theoretic; Inductive, learning, data mining
- Constraints: satisfaction, optimization

- Trust policies for firewalls, confidentiality, security, privacy, access control
- E-Contracting end-to-end reuse, power: incl. business process monitoring
- Policy Ontology, Services Ontologies, Relationship to C++/Java/C# Inheritance
- Web Services "Policy Management", "Contracts"
- Add semantics to existing standards: XBRL, XACML, ebXML, RosettaNet, EDI
- Biomedical: patient records privacy and workflow, drug discovery, treatment safety tracking
- Marketing, intelligence, supply chain, financial reporting, travel
- Business Value Analysis, Strategy, Roadmapping

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OPTIONAL SLIDES FOLLOW

Objectives for Integrating Distributed SW Rules and Ontologies, Motivating SweetRules I

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).*

Criteria for Contract Rule Representation

1

2

3

- *High-level:* Agents reach common understanding; contract is easily modifiable, communicatable, executable.
- Inter-operate: heterogeneous commercially important rule systems.
- Expressive power, convenience, natural-ness.
- ... but: computational tractability.
- Modularity and locality in revision.
- Declarative semantics.
- Logical non-monotonicity: default rules, negation-as-failure.
  - essential feature in commercially important rule systems.
- Prioritized conflict handling.
- Ease of parsing.
- Integration into Web-world software engineering.
- Procedural attachments.

OLP

Courteous

XML

Situated

New Analysis: Key Technical Requirements for SWS

- 1. Combine rules with ontologies, from many web sources, with:
  - Rules on top of ontologies
  - Interoperability of heterogeneous rule and ontology systems
  - Power in inferencing
  - Consistency wrt inferencing
  - Scaleability of inferencing

- 2. Hook rules (with ontologies) up to web services
  - Ex. web services: enterprise applications, databases
  - Rules use services, e.g., to query, message, act with side-effects
  - Rules constitute services executably, e.g., workflow-y business processes
  - Rules describe services non-executably, e.g., for discovery, deal negotiation
  - On top of web service process models, coherently despite evolving messiness

New Fundamental Rule KR Theory I
that enables Key Technical Requirements for SWS

- 1. Courteous Logic Programs: [Grosof]

  KR to combine rules from many sources, with:
  - Prioritized conflict handling to enable consistency, modularity; scaleably
  - Interoperable syntax and semantics

- 2. Situated Logic Programs: [Grosof]

  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

New Fundamental Rule KR Theory II
that enables Key Technical Requirements for SWS

- 3. Reference Ontologies from Rules Via URI Names [Grosof]

- 4. Description Logic Programs: [Grosof, Horrocks, Volz, & Decker]

  KR to combine LP (RuleML) rules on top of DL (OWL) ontologies,

  with:

  – Power in inferencing (including for consistency)
  – Scaleability of inferencing
  – Approach: Analyze and exploit the Intersection of DL and LP (within FOL)

New Fundamental Rule KR Theory III
that enables Key Technical Requirements for SWS

- 5. Courteous Inheritance: [Grosof & Bernstein]
  - OO default inheritance as Courteous LP
  - Used to Leverage Process Handbook, & other Legacy OO Knowledge, to create SW service ontologies
- 6. Production Rules as LP: [Grosof]
  - OPS5-heritage production rules as Situated Courteous LP
  - Find and fix fundamental weakness in chaining through negation in Rete-based inferencing
  - Unify commercially most important and fast-growing rule families
- 7. Hypermonotonic Reasoning: [Grosof (in-progress)]
  - Unify Nonmon LP KR with FOL KR
  - Nonmon LP as sound & incomplete wrt FOL

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

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.
  - SQL99 even has recursive rules.
- Production rules (OPS5 heritage): e.g.,
  - Blaze, ILOG, 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.)*

Slide also by Harold Boley (NRC)

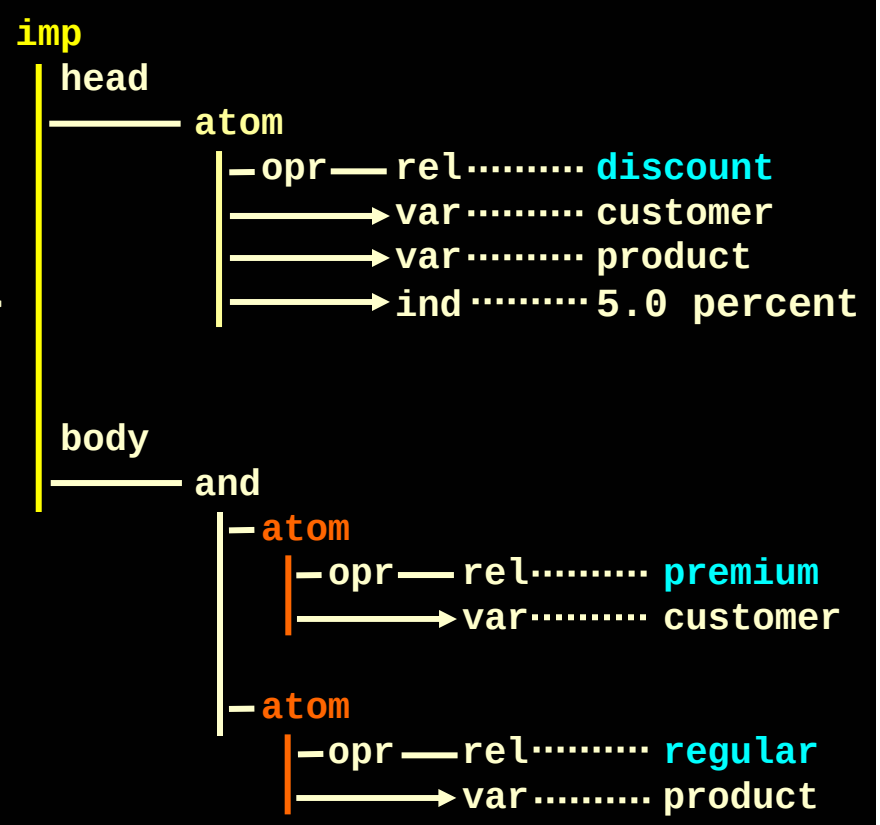
RuleML Example: Markup and Tree

'The **discount** for a *customer* buying a *product* is **5.0 percent** if the *customer* is **premium** and the *product* is **regular**.',

discount(?customer,?product,"5.0 percent") ← premium(?customer) /\ regular(?product);

Markup Syntax

```
<imp>
  <_head>
    <atom>
     <opr><rel>discount</rel></opr>
     <tup><var>customer</var>
          <var>product</var>
          <ind>5.0 percent</ind></tup>
    </atom>
  </head>
  <body>
    <and>
      <atom>
        <_opr><rel>premium</rel></opr>
        <tup><var>customer</var></tup>
      </atom>
      <atom>
        <_opr><rel>regular</rel></opr>
        <tup><var>product</var></tup>
      </atom>
    </and>
  </body>
</imp>
```



`tup` is an ordered tuple.

Sea Change in the Web

- Web software and data infrastructure is undergoing a sea change from HTML to XML... ➔➔
- More detailed descriptions of products/services
- …Exchanged more automatically
- …With greater depth of understanding
- ➔ ➔ Radical change in e-markets & EAI
  - integration of e-business processes
  - ... across organizations & applications
  - example: supply chain

Big Questions
about the New Generation Web

- What are the critical features/aspects of the new technology?
- What business problems does it help solve?
- What are the likely innovation evolution paths, and associated entrepreneurial opportunities?

More Research Aspects/Questions about the New Generation Web

- Core technologies: Requirements, concepts, theory, algorithms, standards?
  - Rules in combination with ontologies; probabilistic, decision-/game-theoretic
- Business applications and implications: concepts, requirements analysis, techniques, scenarios, prototypes; strategies, business models, market-level evolution?
  - End-to-end e-contracting, finance, trust; …

Web Service -- definition

- *(For purposes of this talk:)*

- A procedure/method that is invoked through a Web protocol interface, typically with XML inputs and outputs

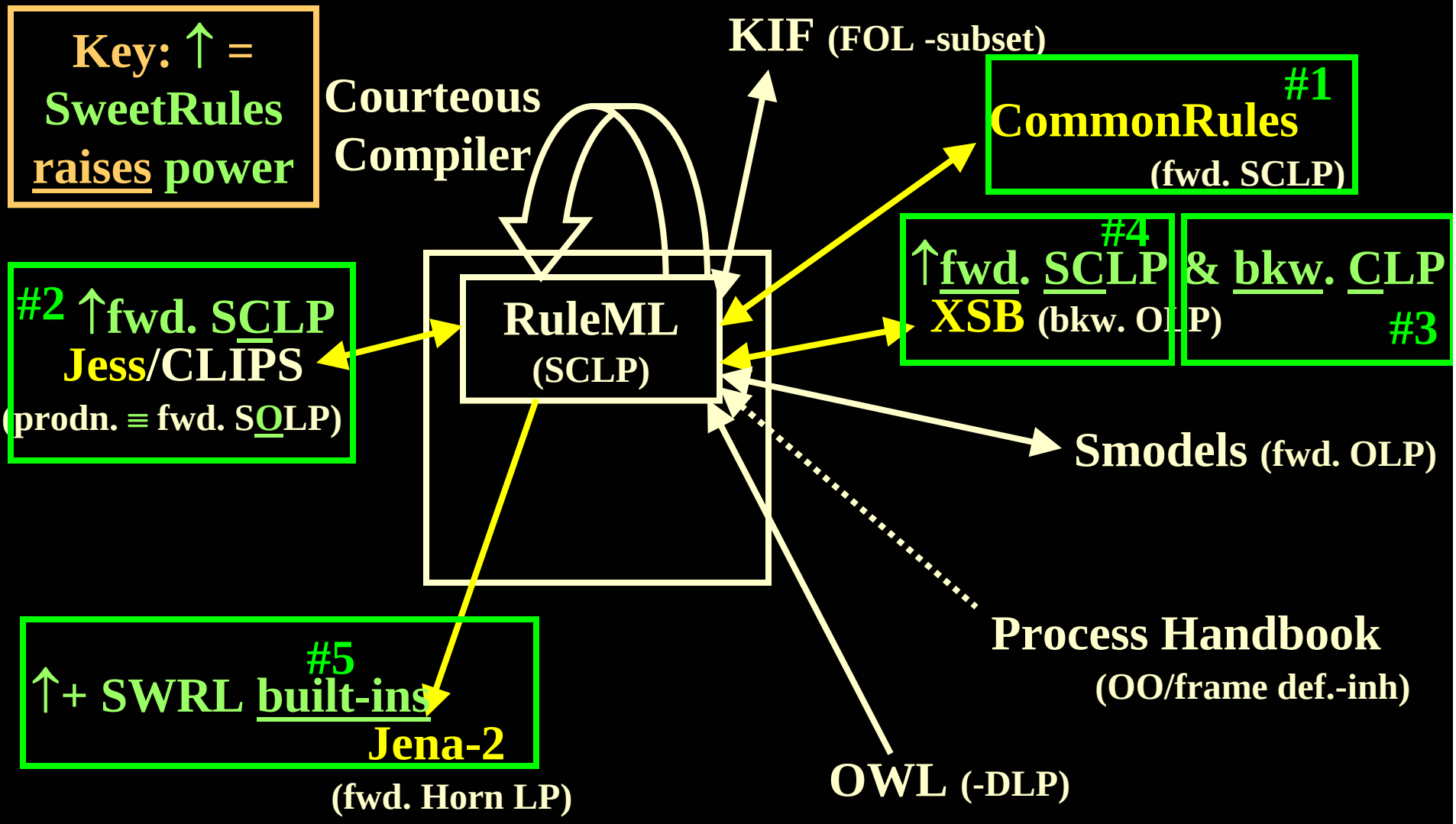
Brief Tour of more relevant websites

- http://www.amazon.com/gp/browse.html/ref=smm_sn_aws/002-8992958-7364050?node=3435361 Amazon's web services – 1000's of developers
- http://zdnet.com.com/2100-1106-975870.html Fidelity's web services for EAI
- Also: the following are about relevant SWS/e-biz standards and related research:
  - http://www.w3.org/2002/ws World Wide Web Consortium, e.g., its Web Services and Semantic Web standards
  - http://www.oasis-open.org Oasis, e.g., its web services and e-biz standards
  - http://www.swsi.org Semantic Web Services Initiative standards – 40 partners
  - http://www.ruleml.org Rule Markup Language Initiative standards, - 30+ partners
  - http://iswc2003.semanticweb.org Intl. Semantic Web Conference – 400 researchers
  - http://ccs.mit.edu/ph MIT Process Handbook, Open Process Handbook Initiative

More about Approach

- Many contract provisions well represented using rules
- Rule language alone is not enough: need communication infrastructure
- approach: communicate rules machine-to-machine/app-to-app using
- and new generation web infrastructure:
  - XML, "Semantic Web" and "Web Services" standards
  - + rule/knowledge engines and editors for developers
- XML messages used for interoperability
- XML aids wrappering and transformation of info between applications/organizations
- communal agreements on schemas and ontologies
- context mappings

OPTIONAL: SweetRules V2.0 New Inferencing Engines



For More Info: ISWC-2004 Tutorial

http://ebusiness.mit.edu/bgrosof/#ISWC2004RulesTutorial

E.g., Part C. Applications -- Policies, Services, and Semantic Integration

- 1. Ontology Translation and Semantic Integration
- - SWRL uses, ECOIN, financial services
- 2. End-to-End E-Contracting and Business Process Automation
- - supply chain, e-tailing, auctions, SweetDeal, Process Handbook
- 3. Business Policies including Trust (authorization, security, privacy, confidentiality, access control)
- - credit, health, RBAC & XACML access control, P3P privacy
- 4. Semantic Web Services
- - SWSL tasks
- 5. Prospective Early Adopter areas, strategy, and market evolution

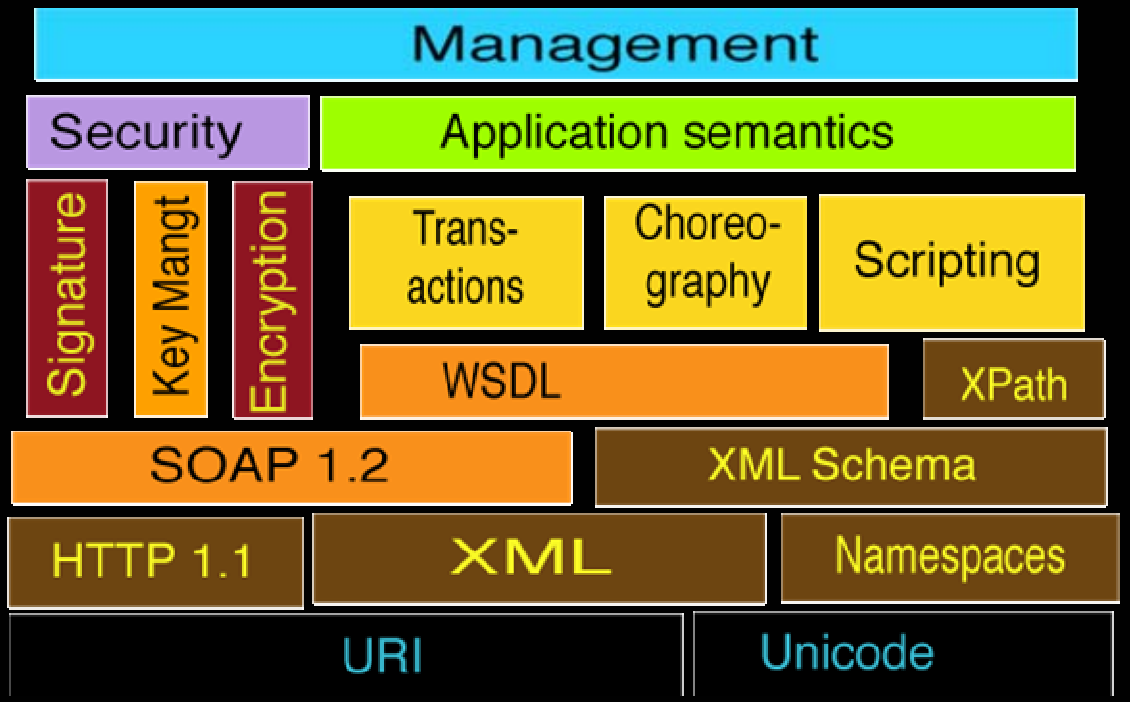
For More Info: the Cover Pages

- http://xml.cover-pages.org
  - Excellent source of info about XML standards and technologies, edited by Robin Cover

Semantic Web Services

- Convergence of Semantic Web and Web Services
- Consensus definition and conceptualization still forming
- Semantic (Web Services):
  - Knowledge-based service descriptions, deals
    - Discovery/search, invocation, negotiation, selection, composition, execution, monitoring, verification
    - Advantage: **reuse** of knowledge across app's, these tasks
  - Integrated knowledge
- (Semantic Web) Services: e.g., infrastructural
  - Knowledge/info/DB integration
  - Inferencing and translation

Web Services Stack outline

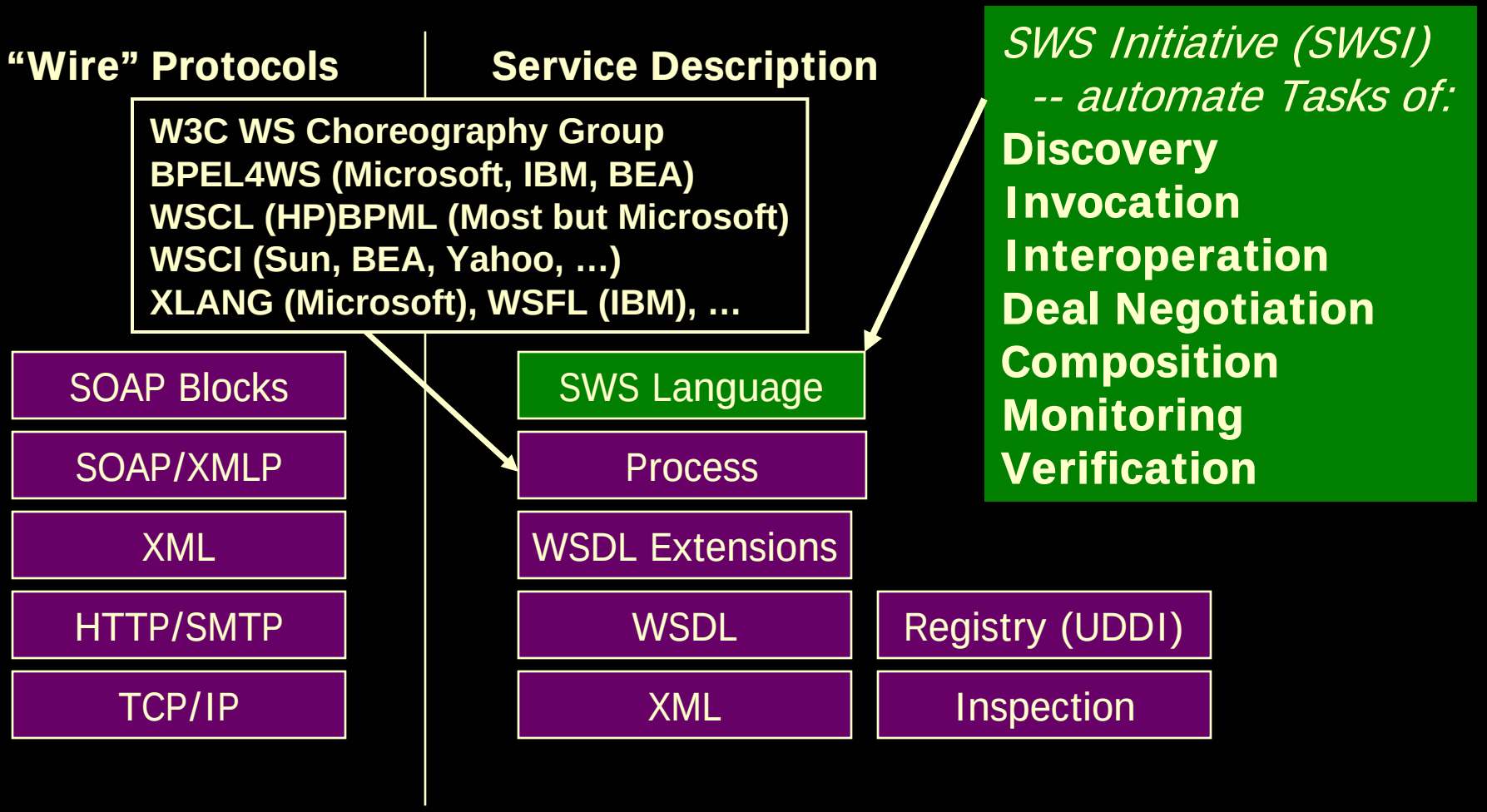


NOTES:

WSDL is a Modular Interface spec
SOAP is Messaging and Runtime
Also:
- UDDI is for Discovery
- BPEL4WS, WSCI, …
  are for transactions
- Routing, concurrency, …

Diagram courtesy Tim Berners-Lee: http://www.w3.org/2004/Talks/0309-ws-sw-tbl/slide6-0.html

SWS Language effort, on top of Current WS Standards Stack



[Slide authors: Benjamin Grosof (MIT Sloan), Sheila McIlraith (Stanford) , David Martin (SRI International), James Snell (IBM)]

Rules in Semantic Web Services: SWSL Strategic Requirements Analysis I

[Grosof, Kifer, Martin et al – SWSI Language Committee May 2004]

- The opportunity for near-term impact of SWS is mostly: …
- Use of LP Rules in: the "SCAMP" group of tasks:
  - SCAMP = Security, Contracts, Advertising, access, authorization, mappings/mediation for semantic interoperability, Monitoring, privacy, and Policies

Overview of RuleML Today III

- Logic Programs is a Fully Declarative KR (not simply Prolog!)
  - Well-established logic with model theory
  - Available algorithms, implementations
  - Close connection to relational DB's
    - core SQL is Datalog Horn LP
- Abstract graph syntax
  - 1st encoded in XML…
  - … then RDF … also a presentation syntax for human editing
- Expressive Extensions incrementally, esp. already:
  - Non-monotonicity: Negation as failure; Courteous priorities
  - Procedural Attachments: Situated actions/effecting, tests/sensing
  - *In-progress:*
    - Hilog, frame syntax, reification cf. F-Logic Programs, SWSL
    - Events cf. Event-Condition-Action

Some Semantic Web Advantages for Biz

- Builds upon XML's much greater capabilities (vs. HTML*) for structured detailed descriptions that can be processed automatically.
  - Eases application development effort for assimilation of data in inter-enterprise interchange
- Knowledge-Based E-Markets -- where Agents Communicate

  (Agent = knowledge-based application)
  - ∴ potential to revolutionize *interactivity* in Web marketplaces: B2B, …
- Reuse same knowledge for multiple purposes/tasks/app's
  - Exploit declarative KR; Schemas

- * new version of HTML itself is now just a special case of XML

WS Stack: some Acronym Expansion

- SOAP = simple protocol for XML messaging
- WSDL = protocol for basic invocation of Web Services, their input and output types in XML
- Choreography = higher-level application interaction protocols in terms of sequences of exchanged message types, contingent branching
  - There's now a W3C Working Group
- "Agreement" here = agreement between invoker and provider of the service, described at knowledge level
- *Overall: in 2001-2002 lots of proprietary jockeying and de-facto mode testing/pressuring of the open-consortial standards bodies (e.g., of W3C) "riding the tiger". Then more via W3C, Oasis starting in 2003.*

SWS Tasks at higher layers of WS stack

Automation of:

- Web service discovery

  Find me a shipping service that will transport frozen vegetables from San Francisco to Tuktoyuktuk.

- Web service invocation

  Buy me "Harry Potter and the Philosopher's Stone" at www.amazon.com

- Web service deals, i.e., contracts, and their negotiation

  Propose a price with shipping details for used Dell laptops to Sue Smith.

- Web service selection, composition and interoperation

  Make the travel arrangements for my WWW11 conference.

[Modification of slide also by Sheila McIlraith (Stanford) and David Martin (SRI International)]