Semantic Web Services, Rules, and E-Contracting

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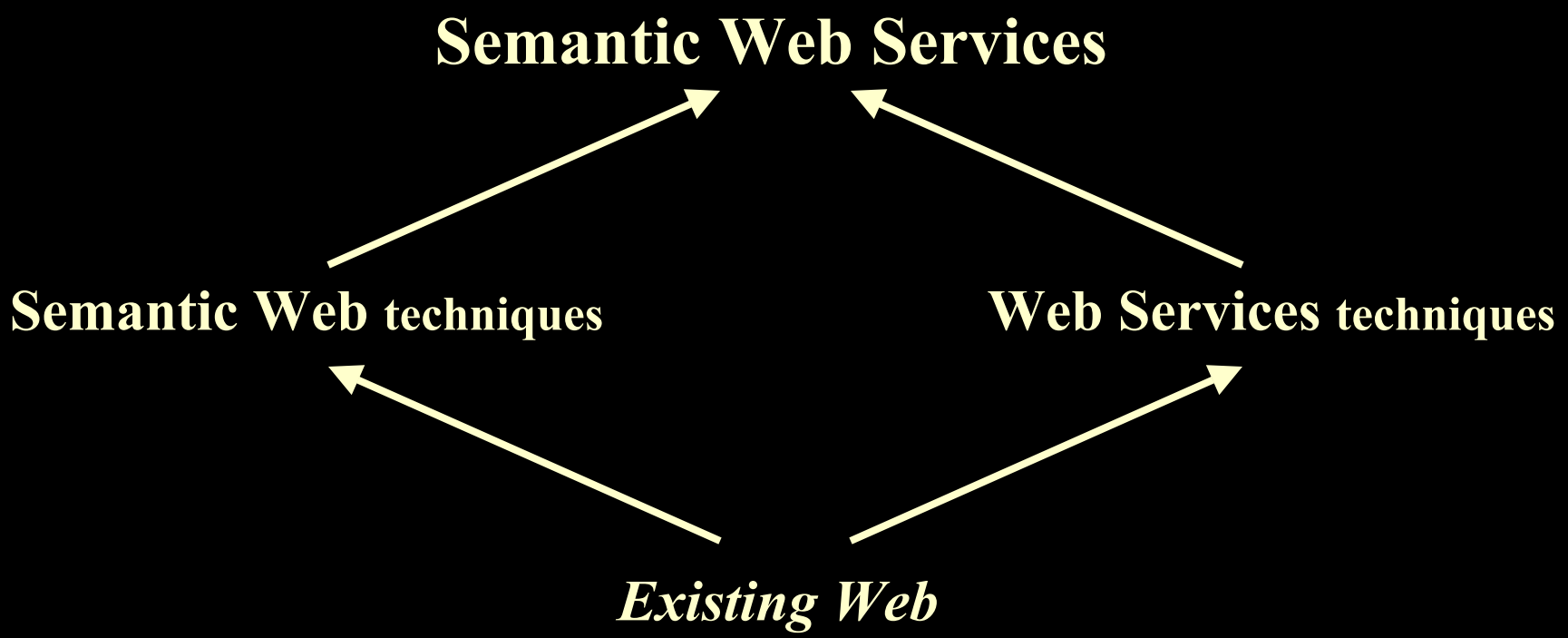
http://www.hbs.edu/doctoral/programs/itm/index.html

Outline of Talk

- I. Overview: Semantic Web Services (SWS) and Rules
  - Concepts, Today's Scene, Visions
  - Applications, incl. B2B
- II. E-Contracting via Rule-based SWS
  - SweetDeal Approach, Application Scenario
- III. Overall Requirements and Uses for Rule-based SWS
- IV. Research Directions
  - Theory, Applications, Technologies, Strategy

Next Generation Web



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

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 proposed 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 proposed 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

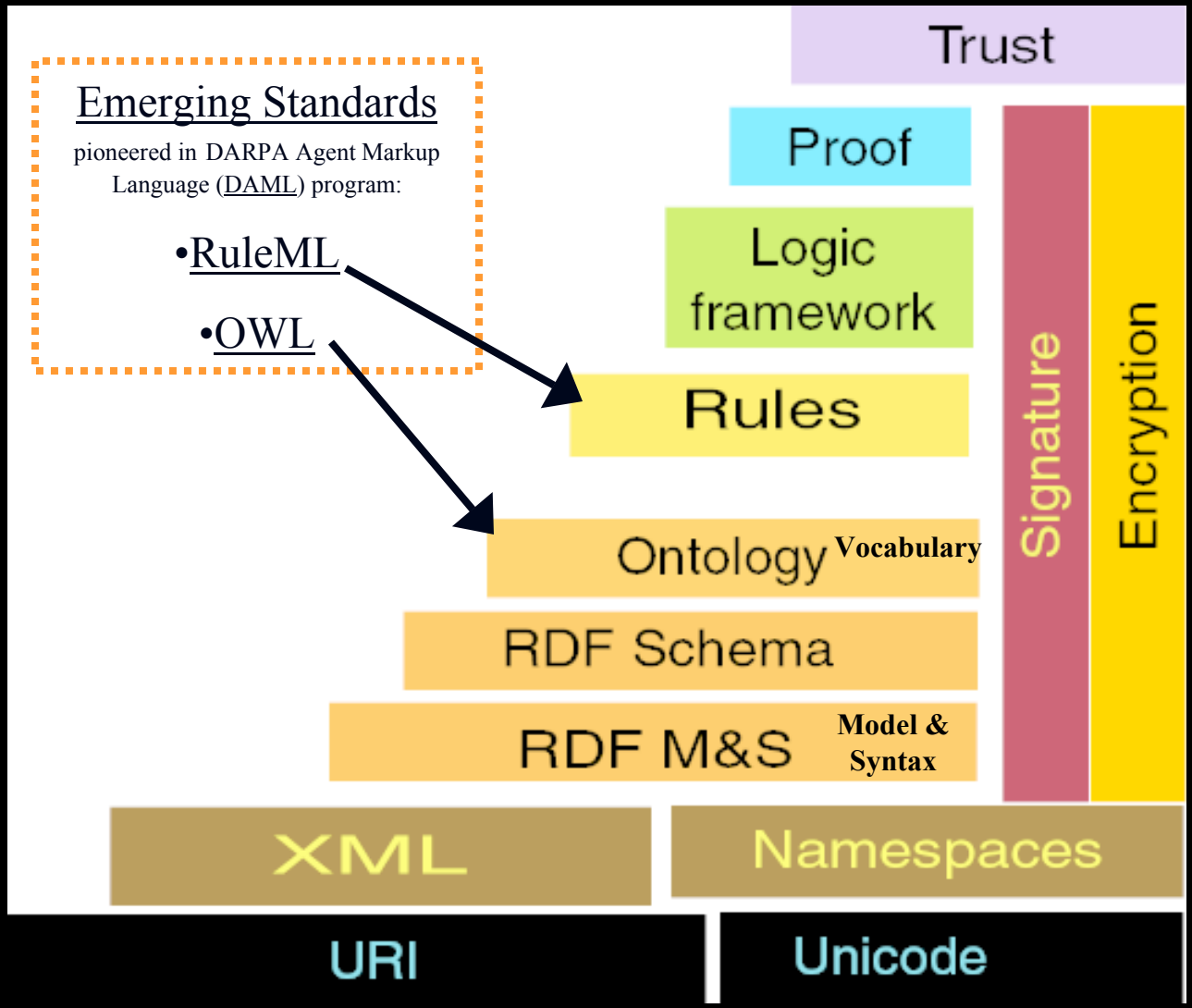
Some Semantic Web Advantages for Biz

- 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

W3C Semantic Web "Stack": Standardization Steps

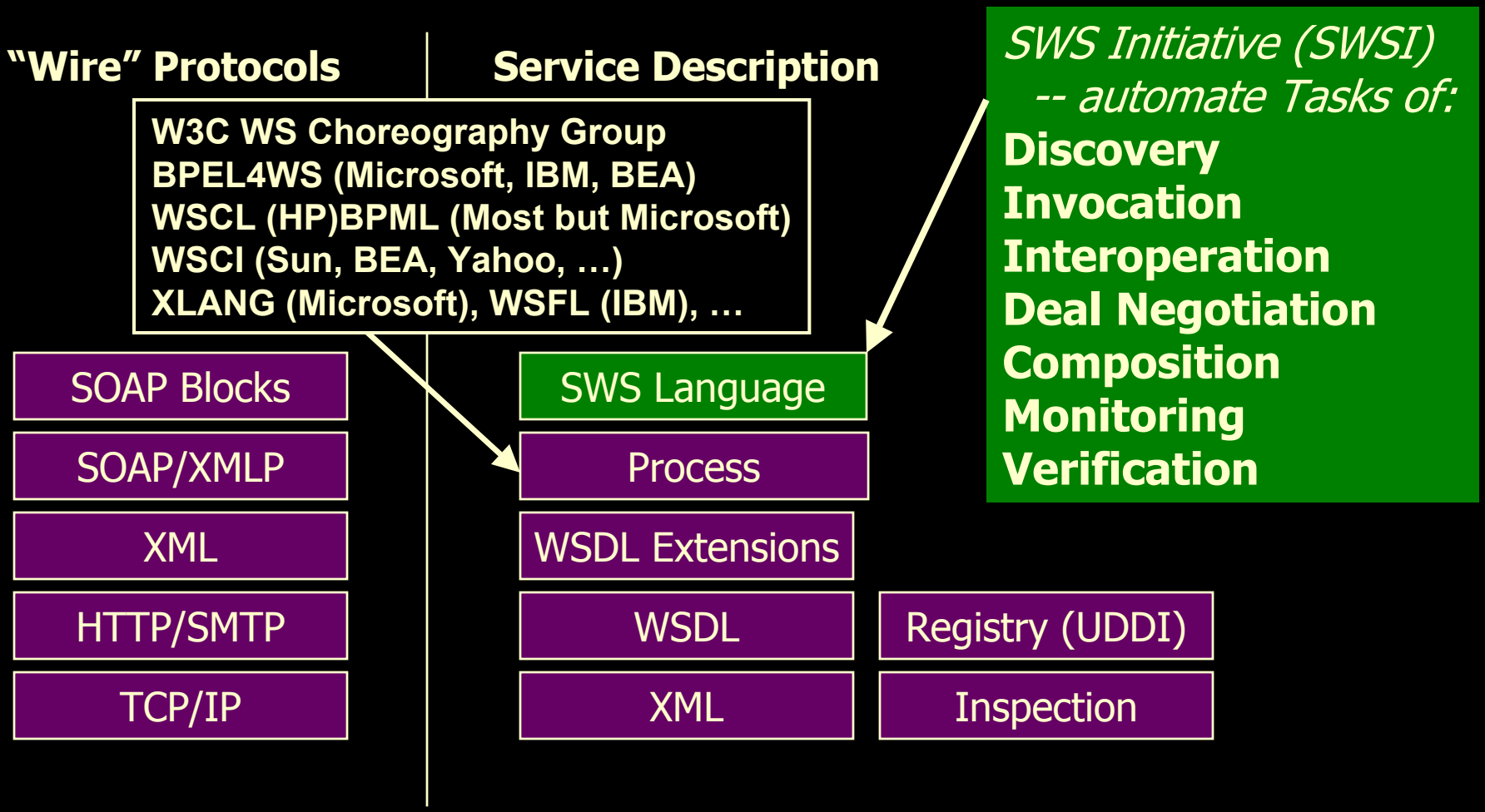


[Diagram http://www.w3.org/DesignIssues/diagrams/sw-stack-2002.png is courtesy Tim Berners-Lee]

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
  - Integrated knowledge
- (Semantic Web) Services: e.g., infrastructural
  - Knowledge/info/DB integration
  - Inferencing and translation

SWS Language effort, on top of Current WS Standards Stack



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B2B Tasks: Communication for Business Processes with Partners

- B2B business processes involving significant Communication with customers/suppliers/other-partners is overall a natural locus for future first impact of SWS.
- Customer Relationship Management (CRM)
  - sales leads and status
  - customer service info and support
- Supply Chain Management (SCM):
  - source selection
  - inventories and forecasts
  - problem resolution
  - transportation and shipping, distribution and logistics
- orders; payments, bill presentation

Some B2B Tasks (continued)

- bids, quotes, pricing, CONTRACTING; AUCTIONS; procurement
- authorization (vs. authentication) for credit or trust
- database-y: e.g.,
  - catalogs & their merging
  - policies
- inquiries and answers; live feedback
- notifications
- trails of biz processes and interactions
- ratings, 3rd party reviews, recommendations
- knowledge management with partners/mkt/society

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*

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.

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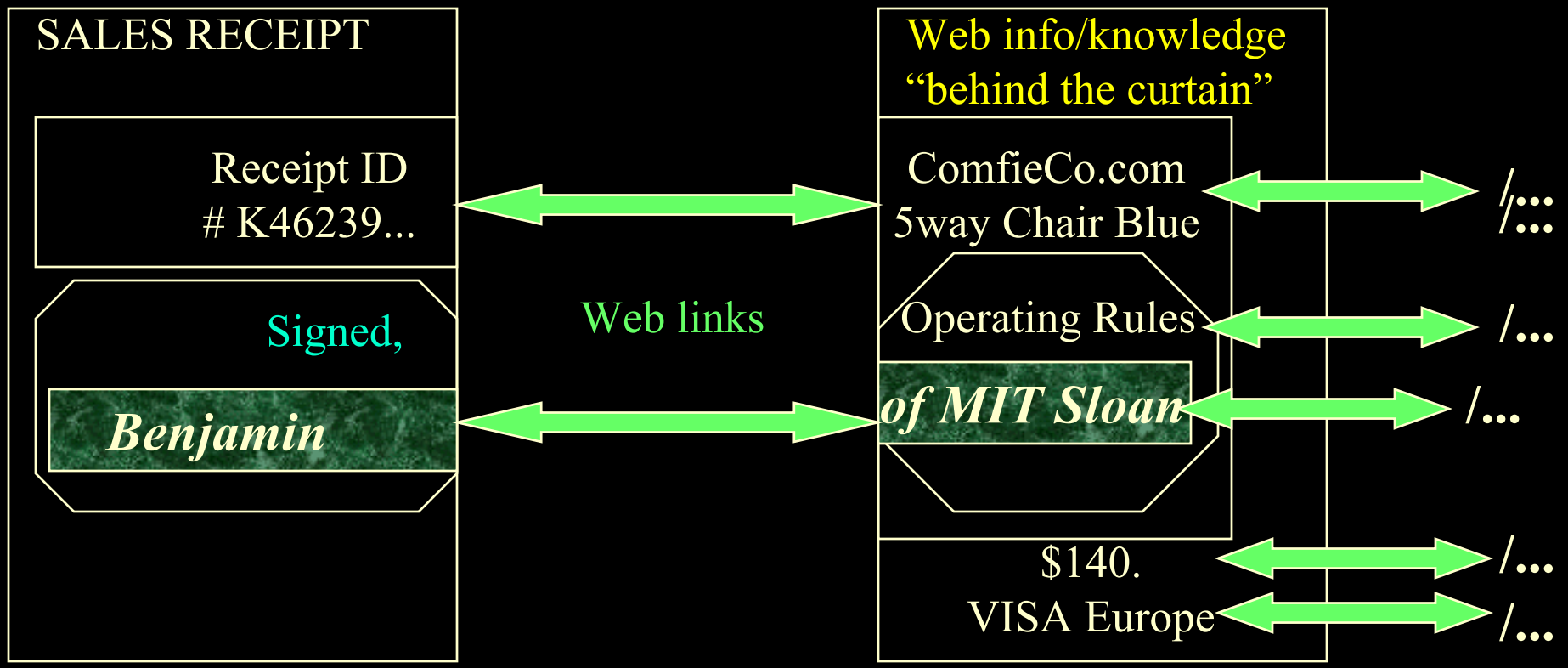
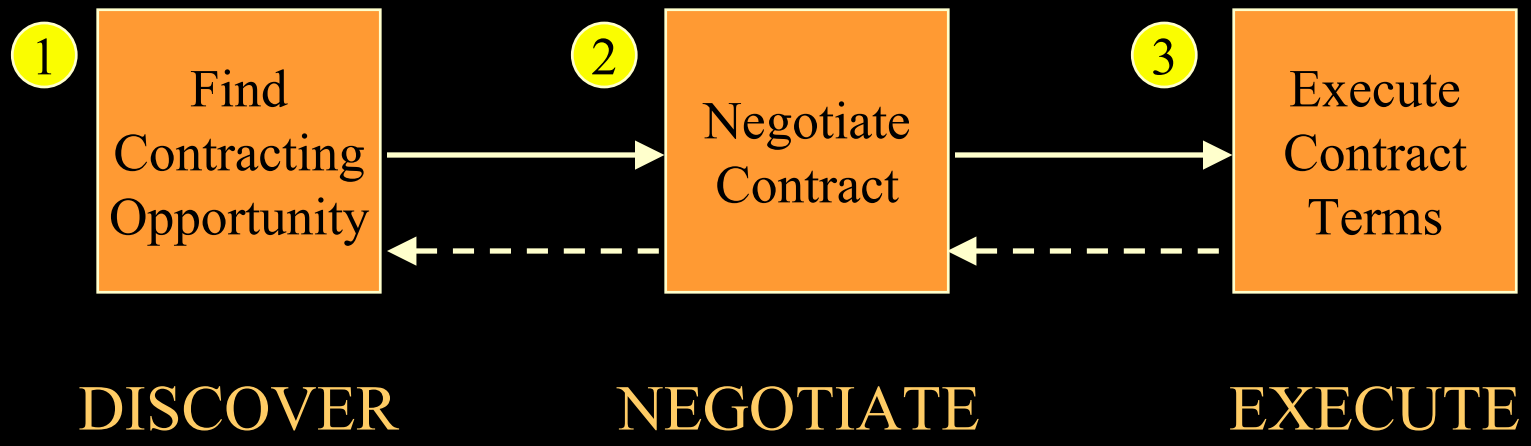
Looks Simple To Start... then Gets Interestingly Precise

A Vision/Approach of what Web & Agents enable



Contracting 1-2-3



- Applies to any contracting, electronic or not.
- May iterate or interleave these steps.
- Boundaries not necessarily sharp.

What's Doable Today *in rule-based agent contracting, based on our approach to rule representation ("SweetDeal")*

- Communicate: with deep shared semantics
  - XML, inter-operable with same sanctioned inferences
  - ⇔ heterogeneous rule systems / rule-based 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)*

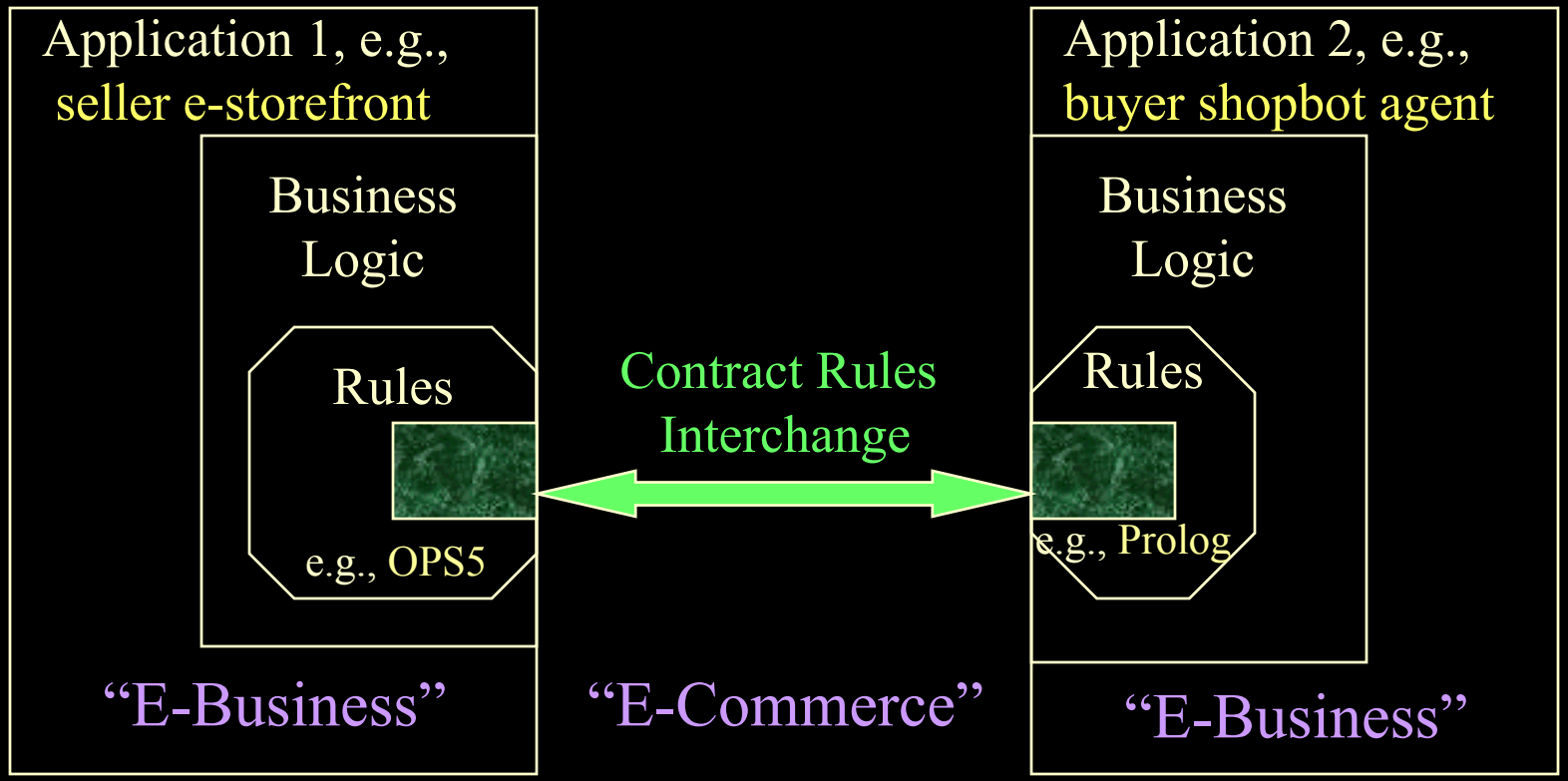
Approach: Rule-based Contracts for E-commerce

- 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.

our SweetDeal Approach

- SWEET = Semantic WEb Enabling Technology
  - software components, theory, approach
  - pilot application scenarios, incl. contracting (SweetDeal)
- Uses/contributes *emerging standards* for XML and knowledge representation:
  - RuleML (co-founder)
  - WebOnt ontologies (W3C)
- Uses *repositories* of business processes and contracts
  - MIT Process Handbook (Sloan IT)
  - legal/regulatory sources: law firms, ABA, CommonAccord, … *Suggestions welcome!!*

Contract Rules across Applications / Enterprises

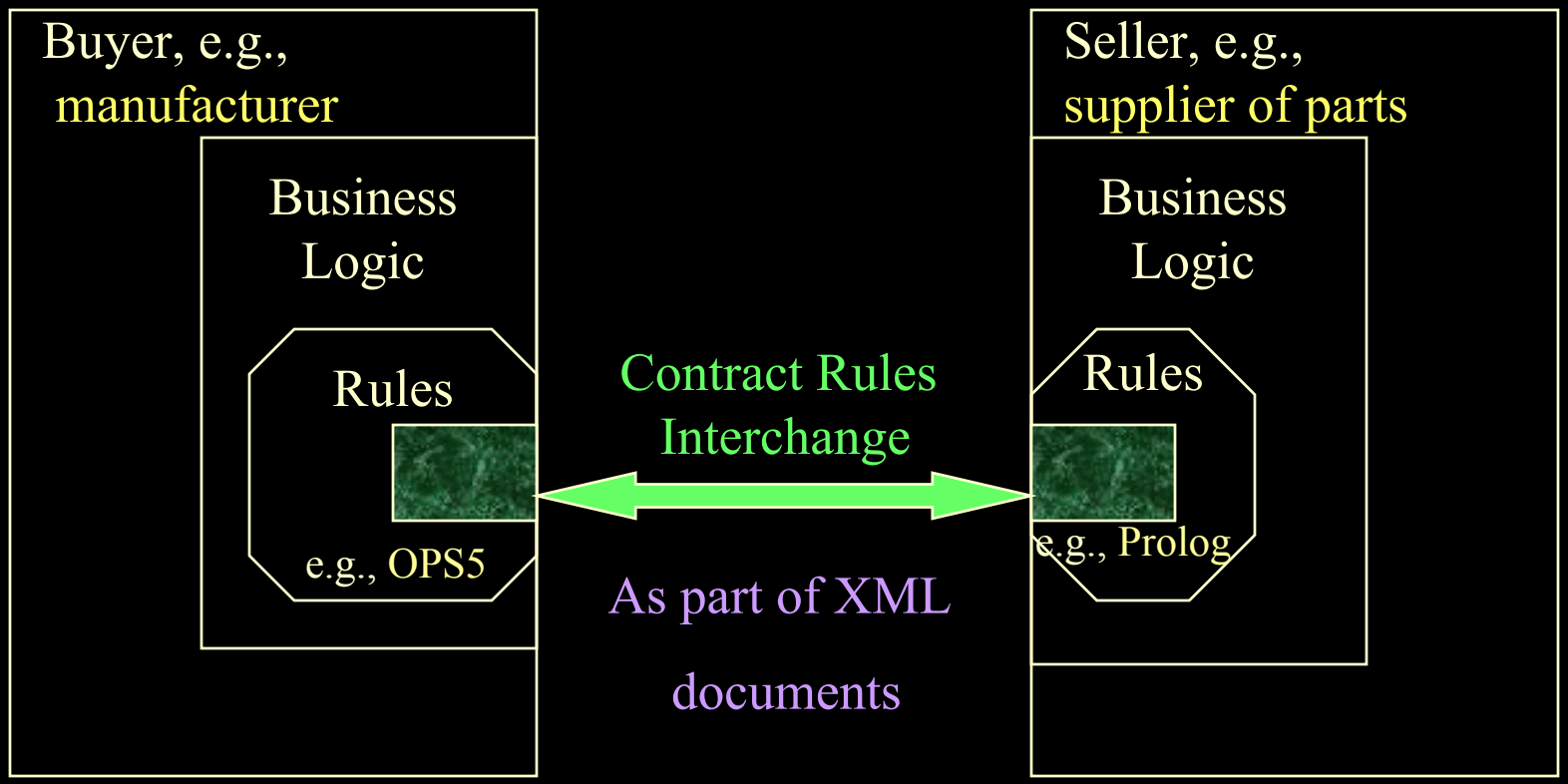


Contracting parties integrate e-businesses via shared rules.

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

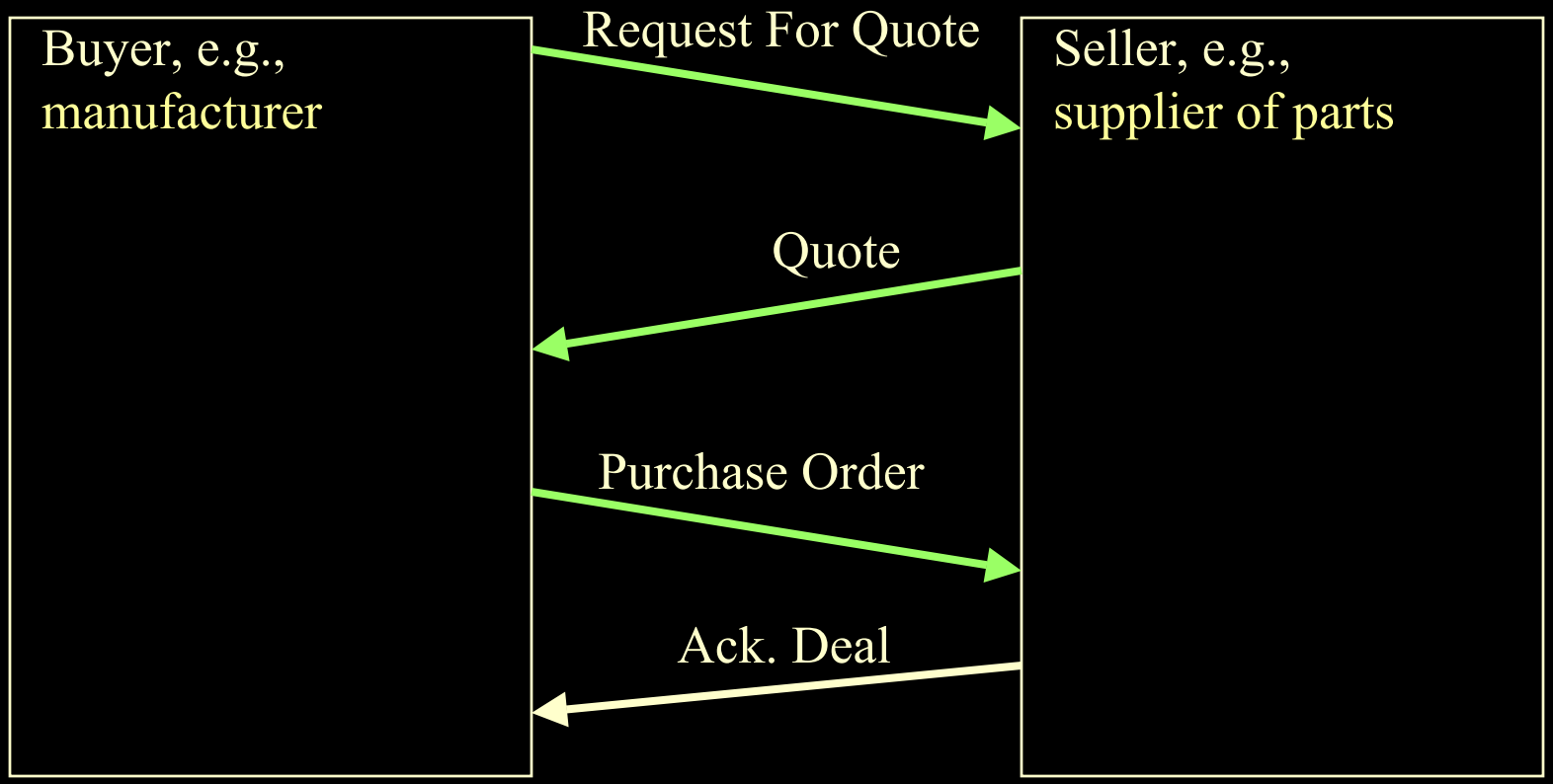
- Product descriptions
  - Product catalogs: properties, conditional on other properties.
- Pricing dependent upon: delivery-date, quantity, group memberships, umbrella contract provisions
- Terms & conditions: refund/cancellation timelines/deposits, lateness/quality penalties, ordering lead time, shipping, 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*

Contract Rules during Negotiation



Contracting parties NEGOTIATE via shared rules.

Exchange of Rules Content during Negotiation: example



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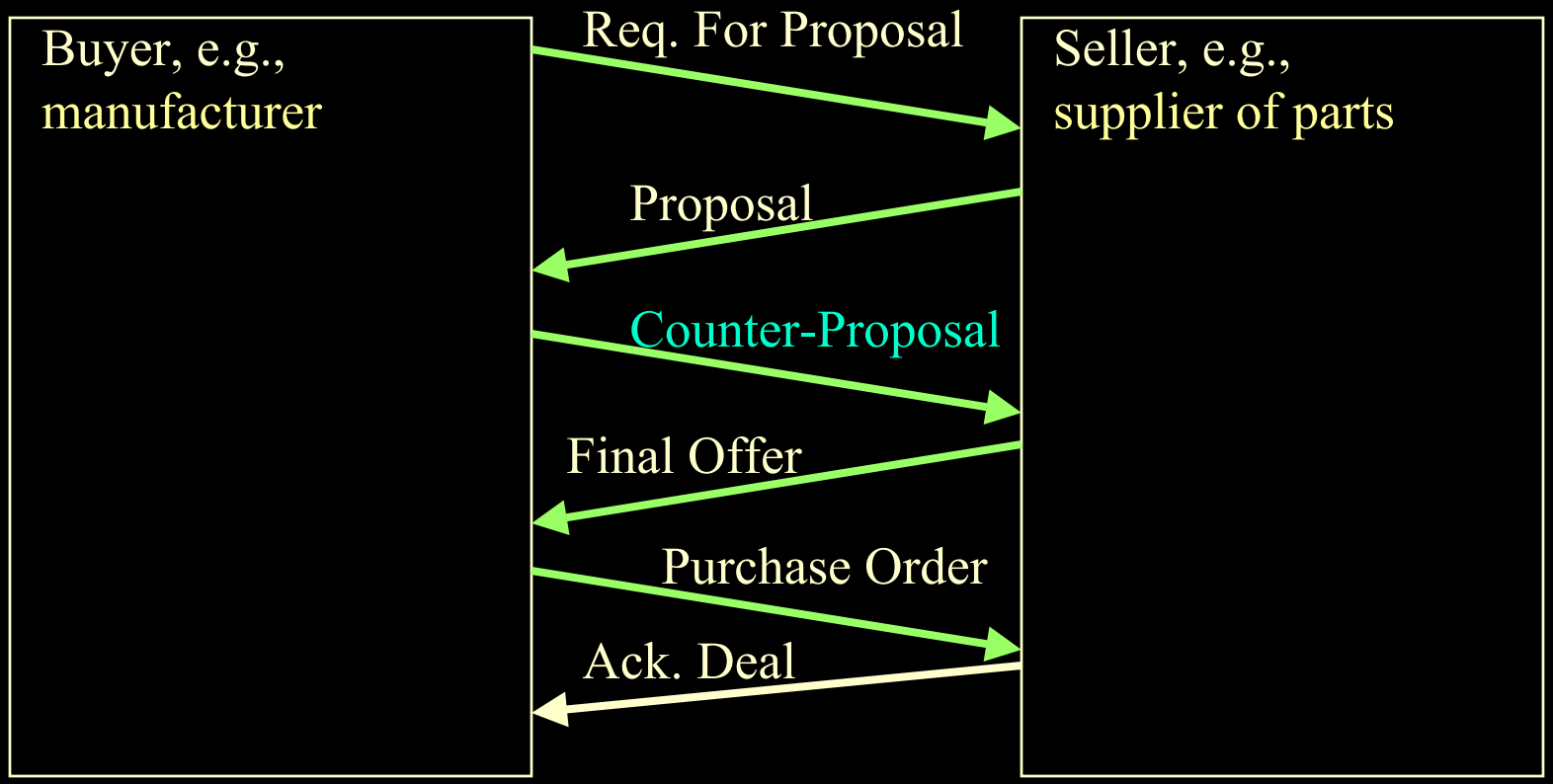

Negotiation Example XML Document: Proposal from supplierCo to manufCo

```
<negotiation_message>
  <message_header>
     <proposal/>
     <from> supplierCo </from>
     <to> ManufCo </to>
   </message_header>
   <rules_content>
          …[see next slide]
   </rules_content>
   …
</negotiation_message>
```

Example of similar message document format:

FIPA Agent Communication Markup Language (draft industry standard).

Courteous LP 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>
   <cslit>
    <_opr><rel>price</rel></_opr>
     <ind>per_unit</ind>
     <var>PO</var>
     <ind>$60</ind>
   </cslit>
  </_head>
  <_body>     …  (see next page)    </_body>
 </imp>
…
</rulebase>
```

Negotiation Example -- XML Encoding of Rules in RuleML, Continued

```
<_body>
  <andb>
    <fclit>
      <_opr><rel>purchaseOrder</rel></_opr>
        <var>PO</var>
        <ind>supplierCo</ind>
        <var>AnyBuyer</var>
    </fclit>
    <fclit>
    …
    </fclit>
    ...
  </andb>
</_body>
```

Commercial Implementation & Piloting

- IBM CommonRules: AlphaWorks Java library
  - implements rule-based capabilities:
    - XML inter-operability; prioritized conflict handling

- Rule Markup Language: nascent industry standards effort
  - XML Knowledge Representation (KR) → make the Web be "Semantic"
  - KR: **Situated Courteous Logic Programs in XML**

- EECOMS industry consortium including Boeing, Baan, TRW, Vitria, IBM, universities, small companies
  - $29Million 1998-2000; 50% funded by NIST ATP
  - application piloted
    - contracting & negotiation; authorization & trust

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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.)*

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.

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

Also Currently Being Developed in the world today

- Delegations between agents
- XML Ontologies (Vocabularies)
  - knowledge representation: infer with definitional knowledge
  - specific domain/industry vocabularies
- DARPA Agent Markup Language: ontologies, rules
- Industry Standards:
  - Web, incl. Web services
  - Agents, Business Processes, Workflow
  - E-Commerce: ebXML, ...
  - Industry-Specific
  - *Legal XML*
- *Law: Electronic Signatures, …*
- *Reusable Contract doc's on Web: CommonAccord, our work, …*

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

Analysis: High-Level Requirements for SWS

- Support Biz-Process Communication
  - E.g., B2B SCM, CRM
  - E.g., e-contracts, financial info, trust management.

- Support SWS Tasks above current WS layers:
  - Discovery/search, invocation, deal negotiation, selection, composition, execution, monitoring, verification

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

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

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

Research Directions

- Requirements Analysis
- Fundamental KR theory, techniques, tools:
  - Courteous LP, Situated LP, Description LP
  - More: nonmon OO ontologies, multi-agent nonmon, equational ontologies, context mappings, …
- Web Services / Business Processes Knowledge Bases:
  - MIT Process Handbook – *Open-source version coming*
- Standards: Rules (RuleML/DAML), SWS (SWSI)
- Applications: e-contracting, finance, trust mgm., travel
- Fundamental theory for e-contracting
- Strategy wrt SWS uses, adoption, markets

Contributions to Early Standards Efforts: RuleML, SWSI

- RuleML Initiative
  - Co-Lead, Co-Founder
  - RuleML based largely on IBM CommonRules
  - Designed most key RuleML features
  - RuleML already has basic support for Description LP, Situated LP, Courteous LP
- Active in SWSI, esp. on Rules
  - Member of SWS Language committee
  - Co-chair Industrial Partners forum: several dozen companies
  - Technical challenge: representing service pre- / post-conditions, coherently on top of evolving messiness of WS process models (e.g., BPEL4WS)

SW Early Adoption Candidates: High-Level View

- "Death. Taxes. Integration."
- Application/Info Integration:
  - Intra-enterprise
    - EAI, M&A; XML infrastructure trend
  - Inter-enterprise
    - E-Commerce: procurement, SCM
  - Combo
    - Business partners, extranet trend

SWS Adoption Roadmap: Strategy Considerations

- 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
  - increase speed, creates value, increases dynamism
  - macro effects create
    - stability sometimes (e.g., supply chain reactions due to lag; other negative feedbacks)
    - volatility sometimes (e.g., perhaps financial market swings)
  - increase flexibility, decrease lock-in
- Agility in business processes, supply chains

SW Early Adopters: Areas by Industry or Task

- Early SW techniques already in use:
  - e-contracting, supply chain incl. procurement
    - manufacturing, e.g. computer/electronics (RosettaNet), automotive (Covisint),
    - EECOMS pilot (Boeing, IBM, TRW, Baan)
    - office supplies (OBI)
    - retailing: shopbots and salesbots: comparisons, recommendations
    - extensive standards activity: Oasis ebXML, XML eContracts, UN UBL, EDI

SW Early Adopters: Areas by Industry or Task

- *Continued:* Early SW techniques already in use:
  - cyber goods:
    - financial services (rules; onto translation)
    - travel "agency", i.e.: tickets, packages (AI smarts for scheduling)
  - military intelligence (e.g., funded DAML)

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Acknowledgements

- SweetDeal e-contracting: student: Terrence Poon
- Situated Courteous Logic Programs: collaborator on implementation: Hoi Chan
- RuleML design: collaborators: Harold Boley, Said Tabet

- Support for the work was provided by DARPA Agent Markup Language program and Center for eBusiness @ MIT Vision Fund

OPTIONAL SLIDES FOLLOW

OWL: SW ontologies KR standard

- Draft Standard of W3C Web Ontologies Working Group (only about a year old), closely based on DAML+OIL precursor from research community. Uses RDF as syntax, extends RDF Schema.
- Based on Description Logic, a logical KR that has subset of expressiveness of first-order classical logic.
- Enables one to represent class hierarchies plus some more expressiveness, e.g., about cardinalities of properties and overlaps of classes.
- Still needs more theoretical and practical work to interoperate and bridge with conventional database schemas (e.g., Entity-Relationship (E-R) models and UML and SQL) and software engineering inheritance (e.g., class hierarchies in object-oriented (OO) langauges such as Java and C++).
- Description Logic's commercial adoption, deployment, and application is much much less (yet) than Rules', and hugely less than OO/E-R/UML/SQL.

Prioritized argumentation in an opposition-locale.

Conclusions from opposition-locales previous to this opposition-locale {p1,...,pk}

(Each pi is a ground classical literal. $k \geq 2$.)

↓

Run Rules for p1,...,pk

↓

Set of Candidates for p1,...,pk:
Team for p1, ..., Team for pk

↓

Prioritized Refutation

↓

Set of Unrefuted Candidates for p1,...,pk:
Team for p1, ..., Team for pk

↓

Skepticism

↓

Conclude Winning Side if any: at most one of {p1,...,pk}

Courteous LP's: Keys to Tractability

- Overall: mutex's & conflict locales $\rightarrow$ keep tractability.
- LP's: disallow disjunctive conclusions, essentially. Classical allows $\Rightarrow$ NP-hard.
- LP's: disallow contraposition (= $\{\neg a \leftarrow . \, , \, a \leftarrow b \wedge c.\} \Rightarrow (\neg b \vee \neg c)\}$) which requires disjunctive conclusions. "Directional". Classical allows $\Rightarrow$ NP-hard.
- Highly expressive prioritized rule representations (e.g., Prioritized Default Logic, Prioritized Circumscription) allow minimal conflict sets of arbitrary size $\Rightarrow$ NP-hard overhead for conflict handling.
- Courteous conflict handling involves essentially only pairwise conflicts, i.e., minimal conflict sets of size 2. (Current work: possibly generalize to size k.)
  - Novelty: generalize to pairwise mutex's beyond $\bot \leftarrow p \wedge \neg p$, e.g., partial-functional, thus avoid need for contraposition and larger conflict sets.
- Courteous conflict handling is local within an opposition locale: a set of rules whose heads oppose each other through mutex's. Refutation and Skepticism are applied within each locale.

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
  - Currently morphing into a W3C activity
- "Agreement" here = agreement between invoker and provider of the service, described at knowledge level
- *Overall: lots of proprietary jockeying and de-facto mode testing/pressuring of the open-consortial standards bodies (e.g., of W3C) "riding the tiger"*

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)]

SWS Tasks at higher layers of WS stack, continued

- Web service execution monitoring and problem resolution
  Has my book been shipped yet? … [NO!] Obtain recourse.
- Web service simulation and verification
  Suppose we had to cancel the order after 2 days?
- Web service executably specified at "knowledge level"
  The service is performed by running the contract ruleset through a rule engine.

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