Representing Ontologies and Integrating them with Rules, for Semantic Policies and Services on the Web

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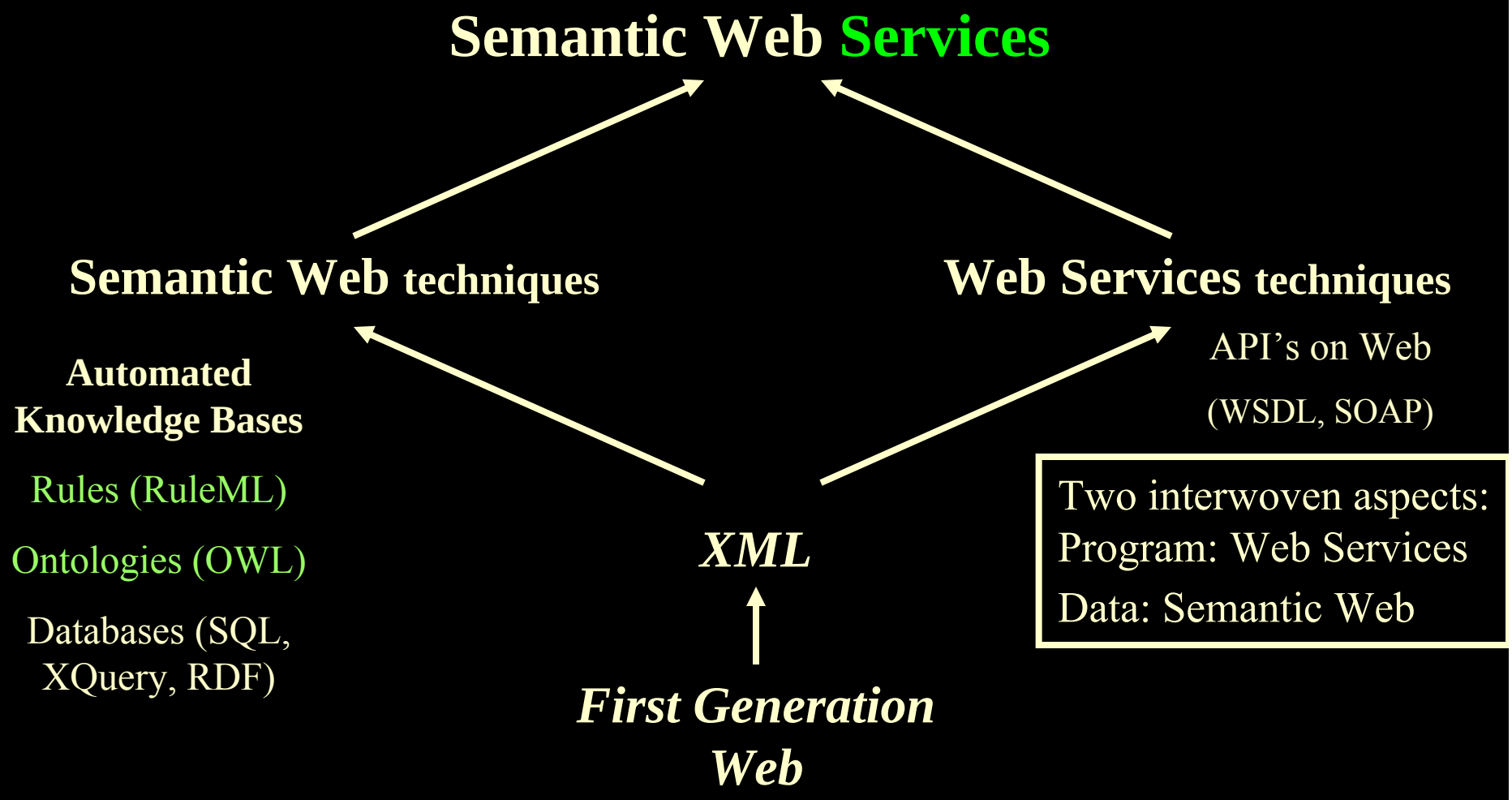
http://www.ai.sri.com

Outline of Talk

- Intro: Research on Semantic Web Services (SWS), its Business Uses
  - Rules, contracting, trust, policies
  - Integration, knowledge representation, standards
- Problem: Reusable Ontological Knowledge to Describe Services
  - Technique: knowledge representation to standardize on
  - Content investment: how to leverage legacy business process K
- New Technical Approach to represent OO Frameworks using SW
  - Courteous Inheritance: default rules increases reuse in ontologies
- New Strategy: go where the knowledge already is, then work outwards
  - Begin with MIT Process Handbook – open-source version in development
    - Example: process knowledge about selling
  - Future: Transformational wrappers around various legacy OO frameworks
- Business Value Analysis and Market/Applications Roadmapping
- *If time: more details on integrating FOL / OWL ontologies into Logic Programs*

Next Generation Web



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?

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; …

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

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.

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)]

Production Logic Programs: A New Fundamental Rule KR Approach

In 2005:

- Production extension of LP:
  - actions and tests appear directly within rules (procedural attachments)
  - Generalizes Situated LP a bit, and reformulates it more familiarly
- Theory & algorithms achieving semantic interoperability of {core Production Rules} ← → declarative LP
  - Handles negation correctly, by stratifying PR agenda control strategy
  - 1st declarative semantics for Production Rules

- Combines with all the other features Courteous, …
- → "Production LP" as umbrella LP KR approach

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

SWS and Rules Summary

*** SWS Tasks Form 2 Distinct Clusters,*

each with associated Central Kind of Service-description Knowledge and Main KR

1. Security/Trust, Monitoring, Contracts, Advertising/Discovery, Ontology-mapping Mediation
   - Central Kind of Knowledge: Policies
   - Main KR: Nonmon LP (rules + ontologies)
2. Composition, Verification, Enactment
   - Central Kind of Knowledge: Process Models
   - Main KR: FOL (axioms + ontologies)
     - + Nonmon LP for ramifications (e.g., cf. Golog)

- Thus RuleML & SWSF specify both Rules, FOL
  - Fundamental KR Challenge: "Bridging" Nonmon LP with FOL
    - SWSF experimental approach based on hypermon. [Grosof & Martin]

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

Future Work Directions

- More scenarios, esp. in SWS policy/SCAMP task cluster
- Integration of more expressive ontologies from OWL, FOL (beyond DLP)
  - Extend DLP in various ways:
    - Use: skolems, integrity constraints, equality, sensing
  - Use hypermonotonic reasoning approach (new KR theory) [SWSF 2005]
    - Map FOL ↔ Courteous LP
    - View nonmon LP as weakened FOL: sound, incomplete
    - E.g., policy rules + background FOL/DL ontologies
- Integration of OO ontologies with default inheritance
- More integration into e-business communication and Web Services, following our SWS vision

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Problem: Reusable Knowledge to Describe Services

- Has two aspects:

1. Technical/technique problem: what form of knowledge? I.e., what knowledge representation to standardize on?

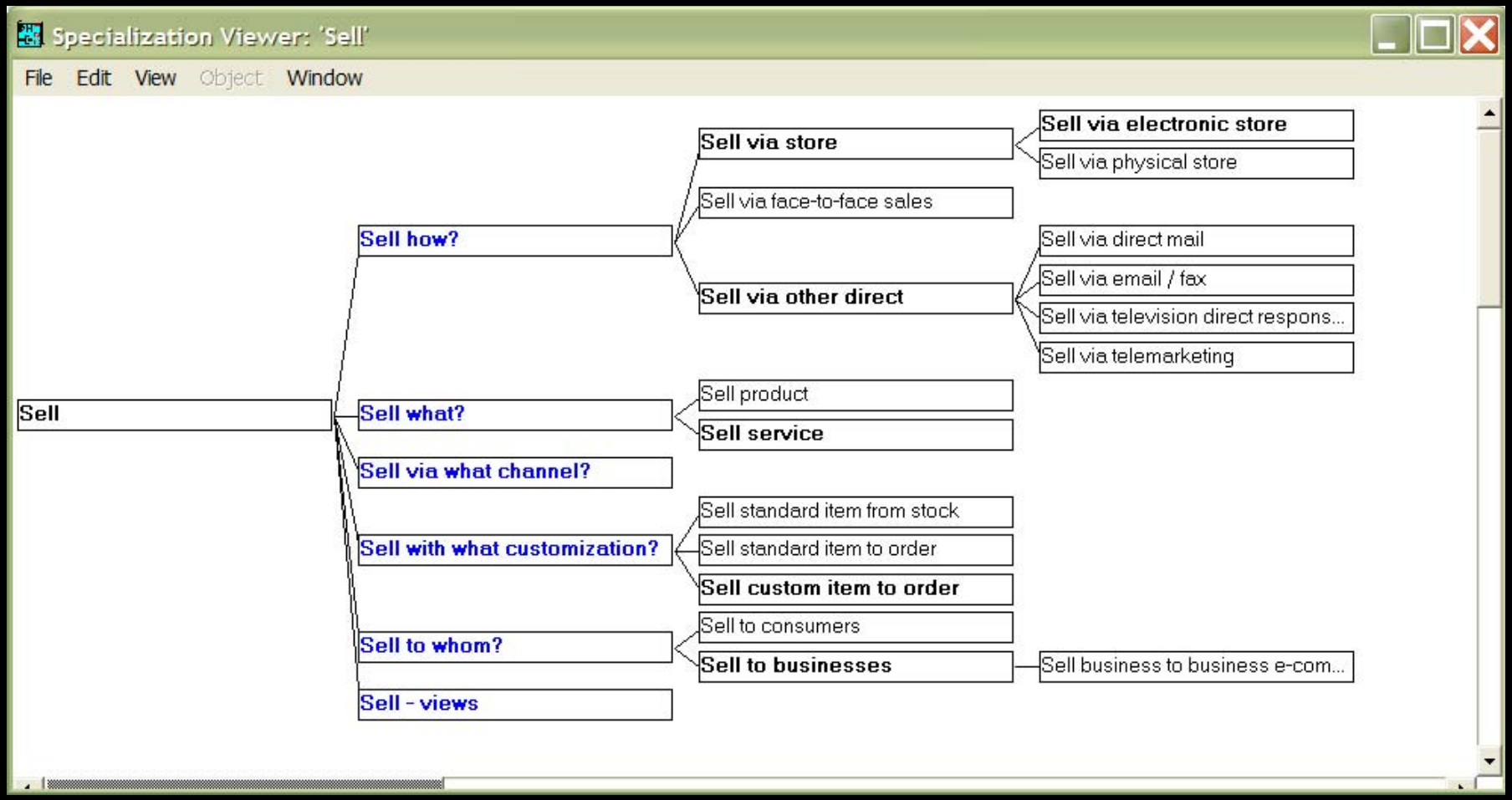
2. Content investment problem: how to leverage to accomplish the reuse of legacy business process knowledge?

Opportunity for Process Handbook in SWS

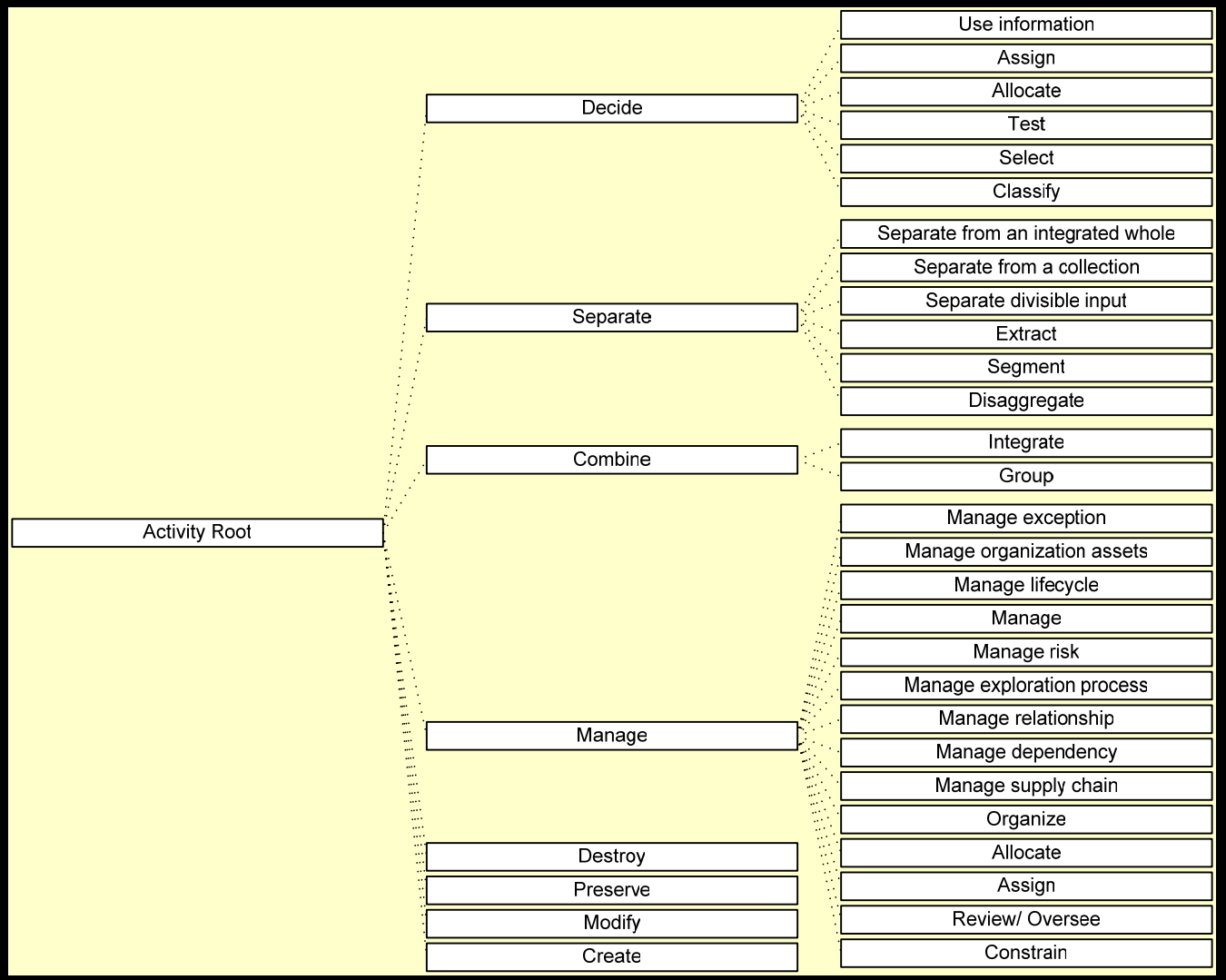
- Need for Shared Knowledge Bases about Web Services / Business Processes
  - For Semantic Web Services, etc.
- Want to leverage legacy process knowledge content
  - Go where the knowledge already is

- Process Handbook (PH) as candidate nucleus for shared business process ontology for SWS
  - 5000+ business processes, + associated class/property concepts, as structured knowledge (http://ccs.mit.edu/ph)
  - E.g., used in SweetDeal E-Contracting prototype
- Concept: Use Semantic Web KR and standards to represent Object-Oriented framework knowledge:
  - class hierarchy, types, generalization-specialization, domain & range, properties/methods' association with classes

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



Some Process Handbook Ontology



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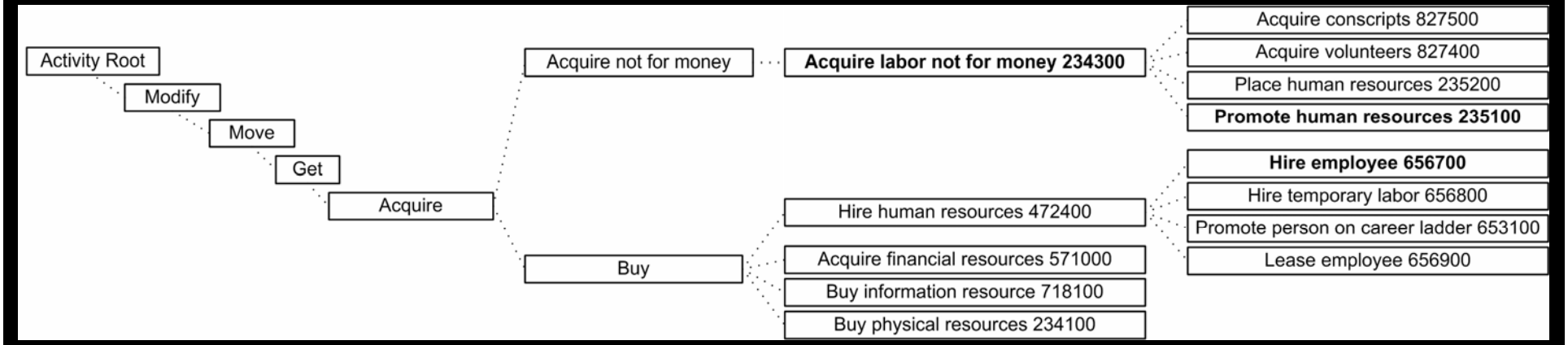
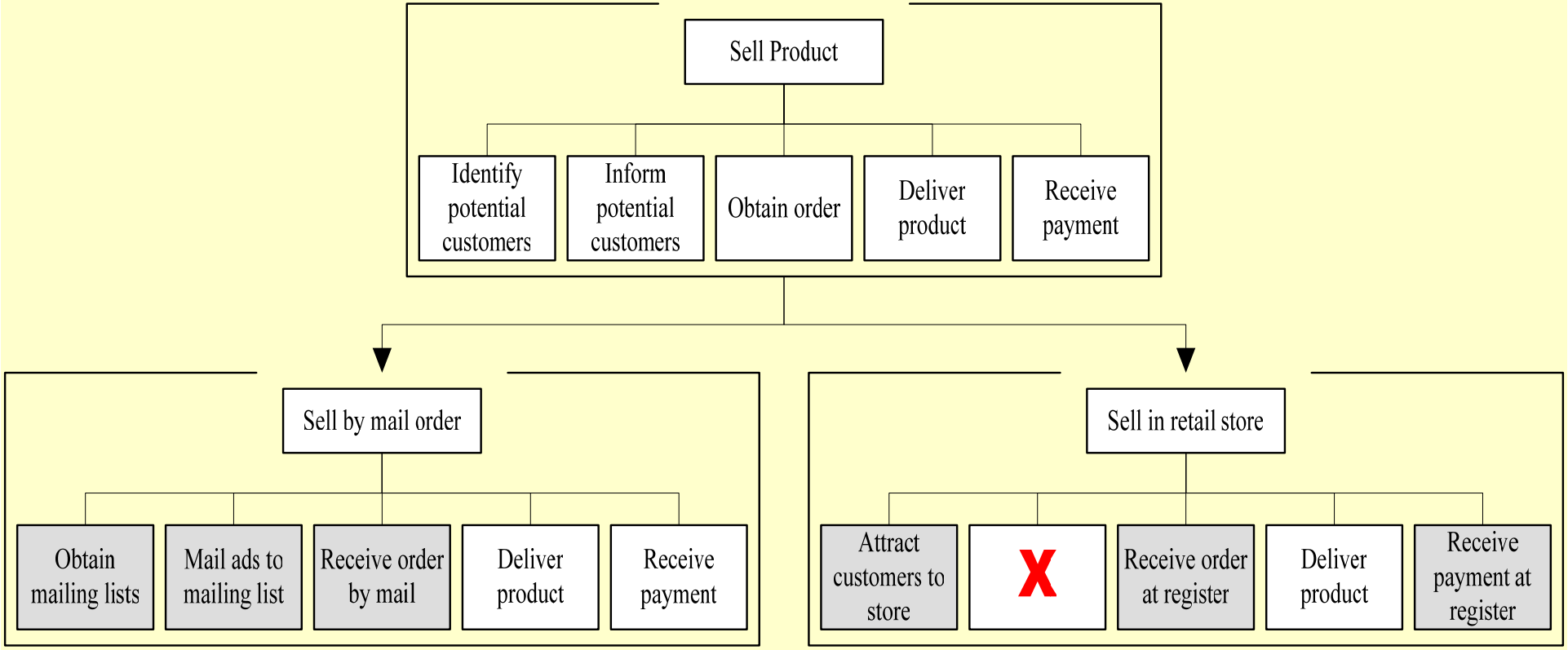


PH Example: Selling Processes



An activity (e.g., SellProduct) has sub-activities (steps).

Its specializations (e.g., SellByMailOrder) inherit its sub-activities by default.

Key: gray = modified (overridden). X = deleted (canceled).

Represent Default-Inheritance Object-Oriented Ontologies Via Courteous LP

- Default-inheritance object-oriented ontologies are ubiquitous in business process realm:
  - Java, C++ frameworks
  - Frame-based systems
- Override or cancel inheritance at subclass.
- OWL, Description Logic, FOL cannot represent default behavior: monotonic only.
- Nonmonotonic/default character increases reuse as compared to monotonic-only.
- Courteous LP can represent them nicely.
  - E.g., SweetPH represents Process Handbook OO business process ontology (5000 processes, 38000 axioms) [Grosof & Bernstein 2003]

Example of Default-Inheritance OO Ontologies in Courteous LP: Via Direct Specification in CLP

```
{buyRegular} paymentMode(?quoteID,invoice) :- Buy(?quoteID).

  /* BuyWithCredit is a subclass of Buy */
Buy(?quoteID) :- BuyWithCredit(?quoteID).

{buyCredit} paymentMode(?quoteID,credit)
                              :- BuyWithCredit(?quoteID).
overrides(buyCredit, buyRegular).
```

SweetPH's New Technical Approach: Courteous Inheritance for PH & OO

- Surprise: use SW *rule* language not the main SW *ontology* language! I.e., use (SCLP) RuleML not OWL.
  - OO inheritance is *default* ⇒ more reuse in ontologies
  - OWL/FOL cannot represent default inheritance
  - RuleML/nonmon-LP can
- Courteous Inheritance approach translates PH to SCLP KR
  - A few dozen background axioms. Linear-size translation. Inferencing is tractable computationally.
- PH becomes a SWS OO process ontology repository
- *In progress: open source version of PH content*
- *In progress: extend approach to OO ontologies generally*

New Technical Approach: Courteous Inheritance in the Process Handbook

- Use SW KR and standards to represent Object-Oriented framework knowledge: class hierarchy, types, generalization-specialization, domain & range, properties/methods' association with classes
- Surprise: use SW *rule* language not the main SW *ontology* language! I.e., use RuleML not OWL.
- Exploit RuleML's nonmonotonic ability to represent prioritized default reasoning as kind of knowledge representation (KR)

New Technical Approach, continued

- Courteous Inheritance KR is built simply on top of the (Situated) Courteous Logic Programs KR of RuleML
  - A few dozen background axioms. Linear-size reformulation. Inferencing is tractable computationally.
- Particularly: represent PH's structured part
  - a scheme specific to PH's flavor of OO
- PH becomes a SWS process ontology repository
  - to be combined, fed, used with/by other SWS
- Kill two birds with one stone:
  - form of K that facilitates leveraging of legacy process K content including PH, OO

New Technical Approach, continued more

- Example(s): selling, PO, price, shipping, delivery, payment, lateness.

- For details, see submitted paper "Beyond Monotonic Inheritance: Towards Semantic Web Process Ontologies" on webpage.
  - Example: selling process

Larger Approach: Transformation Wrappers for OO Frameworks

- New Strategy: go where the knowledge already is, then work outwards
- Future: Transformational wrappers around various legacy OO frameworks
  - C++
  - Java, C#
  - UML
- Can use XSLT, SW tools, and/or XQuery engines to implement the transformations, guided by SWS ontology standardization practices

Market Evolution: Discussion Questions

- Existing and prospective early adopters
- Importance of open source content: seems to be an assumption/axiom for many people
- Prospective sources of open source content

Outline

- Introduction and Context: Semantic Web Services for E-Business; Policies
- Overview: SweetDeal Approach, New Extensions
- More Details: SweetDeal, SCLP, KB merging, SweetRules
- Procurement Scenario
- Fact-queries, as part of communicated KB's
- OO default inheritance ontologies, as Courteous LP
- Relationship to E-Business Messaging Standards / Platforms
- Business Value Analysis
- Conclusions & Future Work

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

- About techniques for integrating OWL and FOL ontologies, including Description Logic Programs

URI Ontological Reference Approach

- A RuleML predicate (or individual / logical function) is specified as a URI, that refers to a predicate (or individual / logical function, respectively) specified in another KB, e.g., in OWL.
- Application pilot and first use case: in SweetDeal e-contracting system (design 2001, prototype early 2002).
- Approach was then soon incorporated into RuleML and adopted in SWRL design (which is based mainly on RuleML), and used heavily there.
- Issue: want to scope precisely which premises in an overall ontological KB are being referenced.
  - Approach in our current work: define a KB (e.g., a subset/module) and reference that KB.

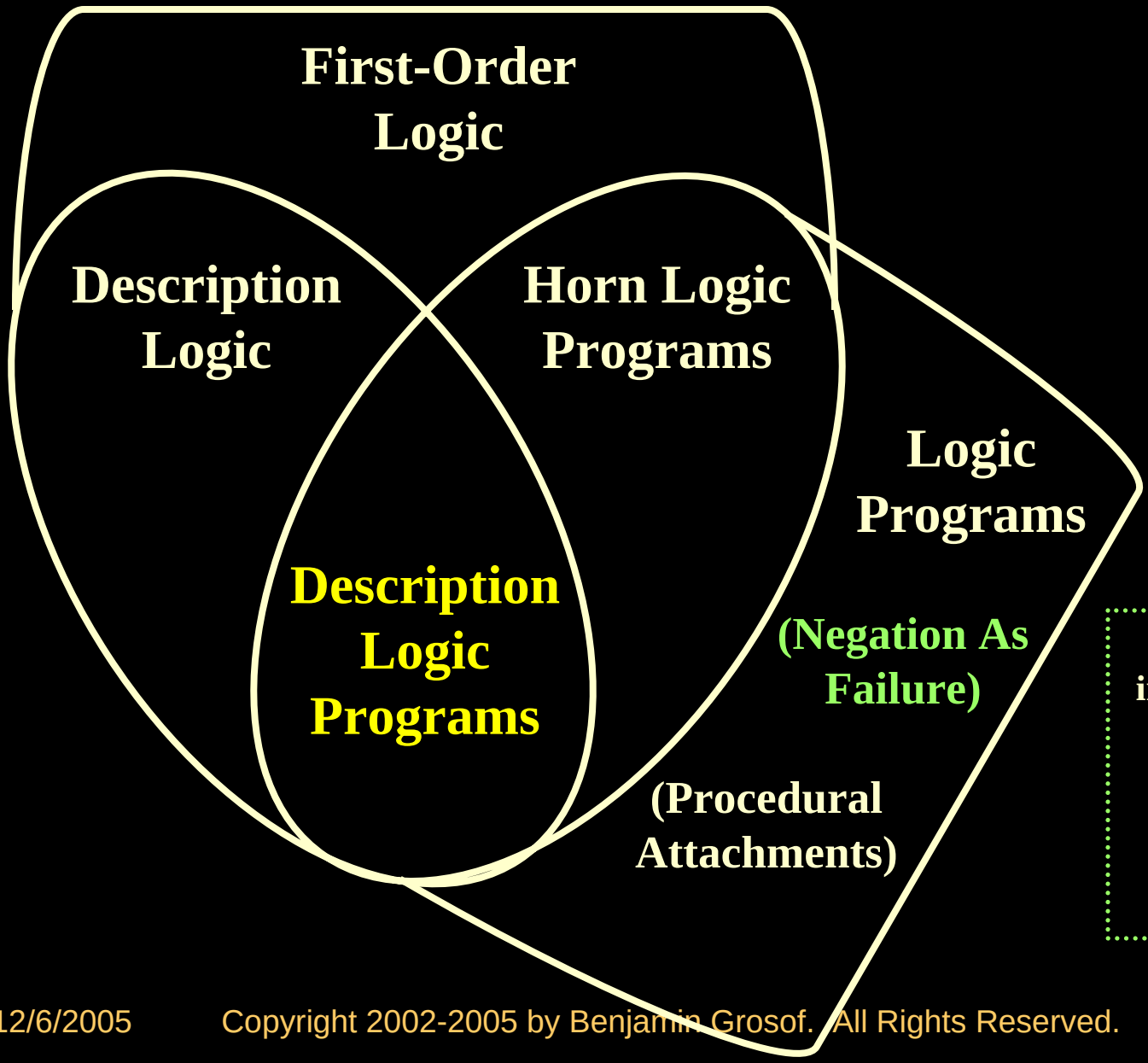
URI Ontological Reference Approach Example, in RuleML

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

SCLP TextFile Format for RuleML

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

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

Venn Diagram: Expressive Overlaps among KR's



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

Overview of DLP KR Features

- DLP captures completely a subset of DL, comprising RDFS & more
- RDFS subset of DL permits the following statements:
  - Subclass, Domain, Range, Subproperty (also SameClass, SameProperty)
  - instance of class, instance of property

- DLP also completely captures more DL statements beyond RDFS:
  - Using Intersection connective (conjunction) in class descriptions
  - Stating that a property (or inverse) is Transitive or Symmetric
  - Using Disjunction or Existential in a *subclass* expression
  - Using Universal in a *superclass* expression
  - ∴ "OWL Feather" – subset of OWL Lite
    - Update summer 2004: New Related Effort is "OWL Lite Minus" by WSMO
- DLP++: enhanced translation into LP can express even more of DL:
  - Using explicit equality, skolemization, integrity constraints
  - Using NAF, for T-box reasoning
  - *(Part still in progress.)*

DLP-Fusion:
Technical Capabilities Enabled by DLP

- LP rules "on top of" DL ontologies.
  - E.g., LP imports DLP ontologies, with completeness & consistency
  - Consistency via completeness. (Also, Courteous LP is always consistent.)
- Translation of LP rules to/from DL ontologies.
  - E.g., develop ontologies in LP (or rules in DL)
- Use of efficient LP rule/DBMS engines for DL fragment.
  - E.g., run larger-scale ontologies
  - $\Rightarrow$ Exploit: Scaleability of LP/DB engines >> DL engines , as |instances| $\uparrow$.
- Translation of LP conclusions to DL.
- Translation of DL conclusions to LP.
- Facilitate rule-based mapping between ontologies / "contexts"

Design Perspective

Alternative points in design space:

1. partial LP + full DL = SWRL V0.6

versus

2. full LP + partial DL = SCLP RuleML V0.8+

(with DLP OWL2RuleML)

(SCLP = Situated Courteous Logic Programs KR)

Need for Other Kinds of Ontologies *besides OWL*

- Kinds of ontologies practically/commercially important in the world today*:
  - SQL DB schemas, E-R, UML, OO inheritance hierarchies, LP/FOL predicate/function signatures; equations and conversion-mapping functions; XML-Schema
- OWL is still emerging.
- Overall relationship of OWL to the others is as yet largely unclear
  - There are efforts on some aspects, incl. UML
- OWL cannot represent the nonmon aspects of OO inheritance
- OWL does not yet represent, except quite awkwardly:
  - n-ary signatures
  - ordering aspects of XML-Schema

- (*NB: Omitted here are statistically flavored ontologies that result from inductive learning and/or natural language analysis.)

Need for Other Kinds of Ontologies *besides OWL, cont.'d*

- Particularly interesting:
  - OO-ish nonmon taxonomic/frames
  - Equations and context mappings cf. ECOIN – can be represented in FOL or often in LP
  - OWL DL beyond DLP
- Builtins (sensed) are a relatively simple kind of shared ontology
  - SWRL V0.6 and forthcoming RuleML V0.9

Default Inheritance cf. OO

- Ubiquitous in object-oriented programming languages & applications
- Default nature increases reuse, modularity
- OWL/DL fundamentally incapable of representing, since monotonic
- Requirements of semantic web service process ontologies:
  - Need to jibe with mainstream web service development methodologies, based on Java/C#/C++
- Approach: Represent OO default-inheritance ontologies using nonmon LP rules
  1. [Grosof & Bernstein] Courteous Inheritance approach
     - Transforms inheritance into Courteous LP in RuleML
     - Represents MIT Process Handbook (ancestor of PSL)
       - 5,000 business process activities; 38,000 properties/values
       - Linear-size transform (n + constant).
     - SweetPH prototype: extends SweetRules
  2. [Yang & Kifer] approach
     - Transform inheritance into essentially Ordinary LP
     - Extends Flora-2

Fundamental KR Challenge in Combining Rules with Ontologies: Unify FOL/DL More Deeply with Nonmon LP

- Motivations: Better support KB merging, SWSL, unify SW overall, more of DL/FOL in LP, handle conflicts between DL/FOL KB's, …

- Approach: "Hypermonotonic" reasoning [Grosof]
  - Courteous LP mapped $\Longleftrightarrow$ clausal FOL
    - Courteous LP always sound wrt FOL
    - … & incomplete wrt FOL
      - Enables: always consistent, robust in merging
    - Mapping is linear-size and local

OPTIONAL SLIDES FOLLOW

- About Situated and Courteous extensions of LP

Review: Situated and Courteous extensions of LP

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

- These extensions combine essentially orthogonally.
  - Sensors may be the subject of prioritized conflict handling, so it is useful to give them labels.

EECOMS Example of Conflicting 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

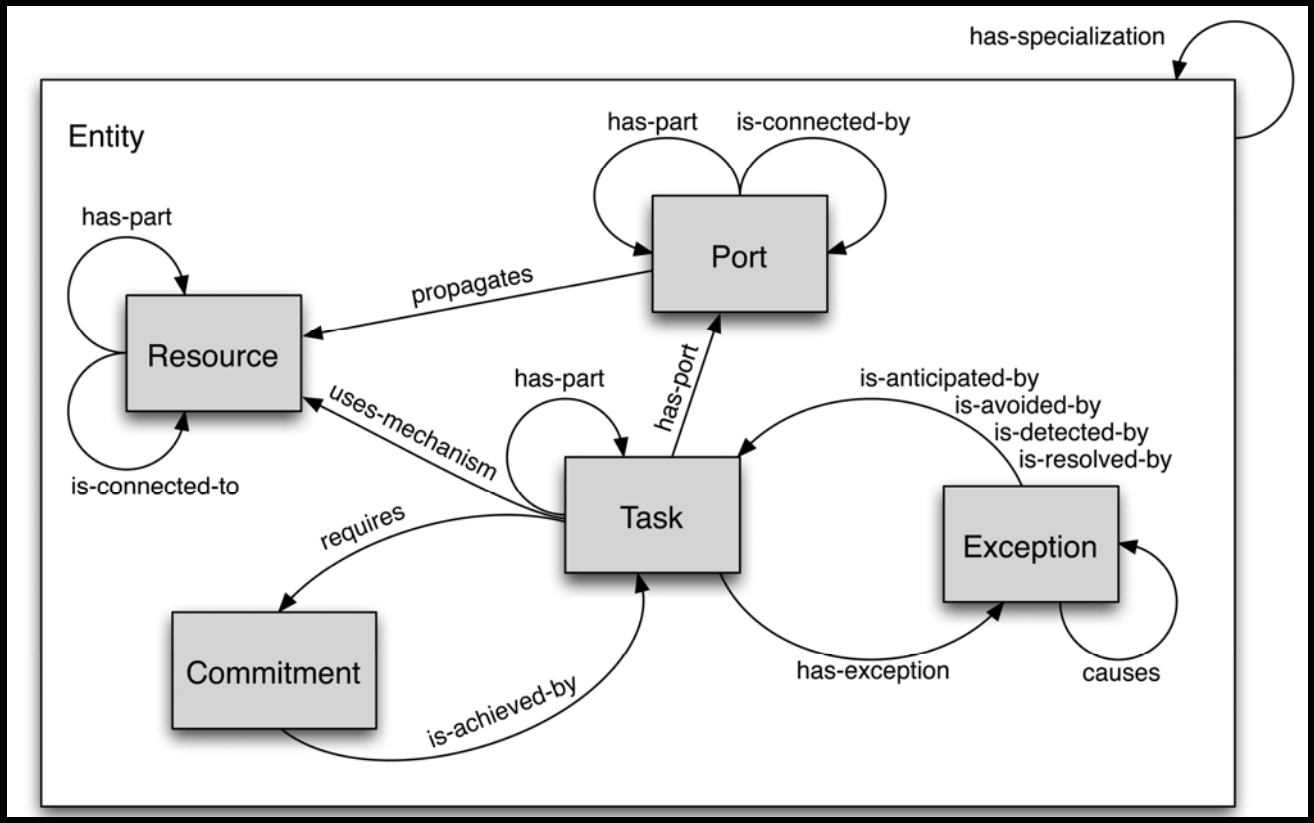
- <leadTimeRule1> orderModificationNotice(?Order,14days)
- ← preferredCustomerOf(?Buyer,?Seller) ∧
- purchaseOrder(?Order,?Buyer,?Seller) .
- <leadTimeRule2> orderModificationNotice(?Order,30days)
- ← minorPart(?Buyer,?Seller,?Order) ∧
- purchaseOrder(?Order,?Buyer,?Seller) .
- <leadTimeRule3> orderModificationNotice(?Order,2days)
- ← preferredCustomerOf(?Buyer,?Seller) ∧
- orderModificationType(?Order,reduce) ∧
- orderItemIsInBacklog(?Order) ∧
- purchaseOrder(?Order,?Buyer,?Seller) .
- overrides(leadTimeRule3 , leadTimeRule1) .
- (⊥ ← orderModificationNotice(?Order,?X) ∧
- orderModificationNotice(?Order,?Y)) ← (?X ≠?Y) .

OPTIONAL SLIDES FOLLOW

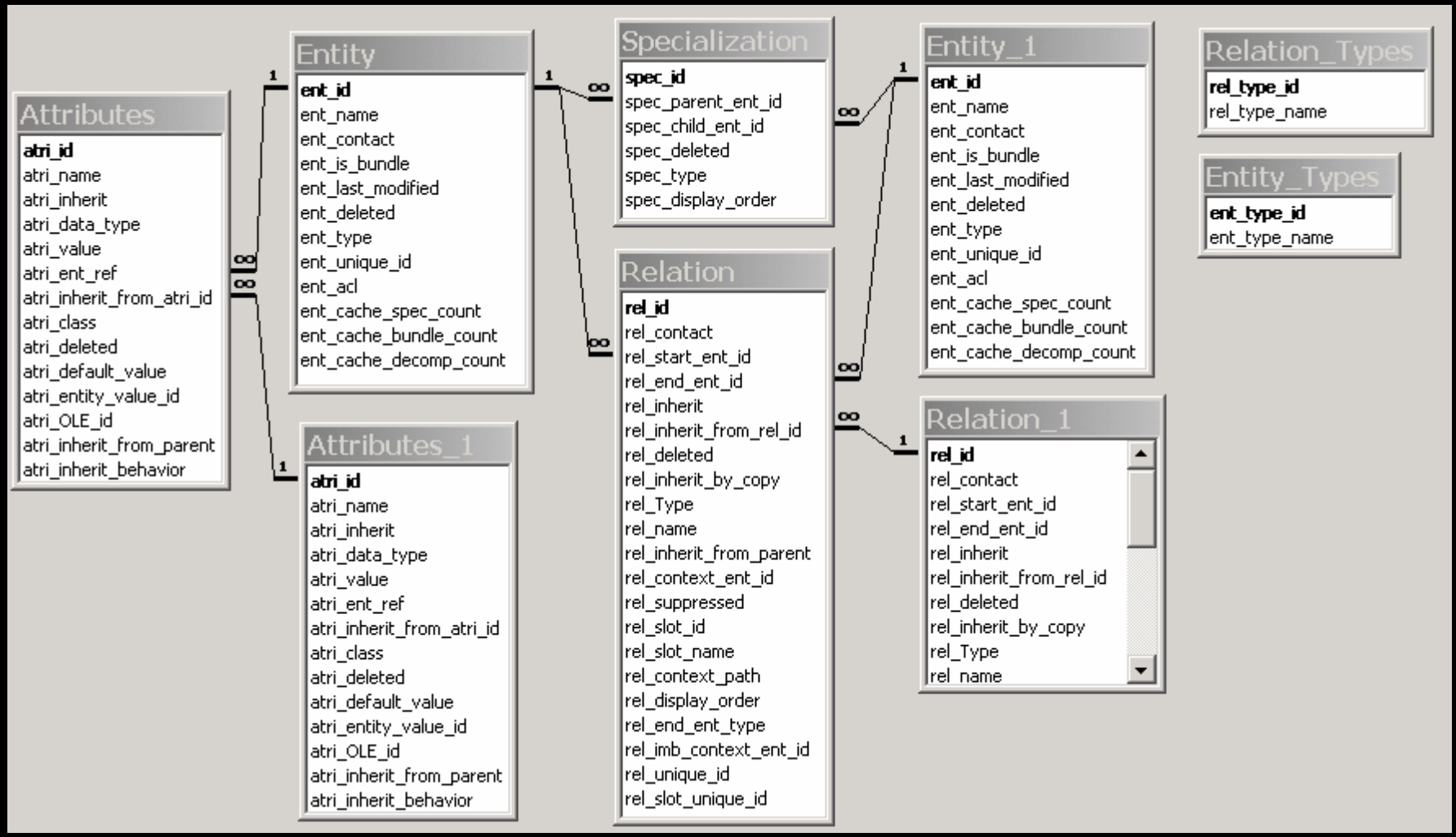
- About Process Handbook and SweetPH

The MIT Process Handbook

- Process repository (built for human consumption)
- Over 5000 processes, ~ 50000 assertions
  - Taxonomy of generic activity types
  - Case examples, on-line discussion forums



Original PH Data Base E-R Model

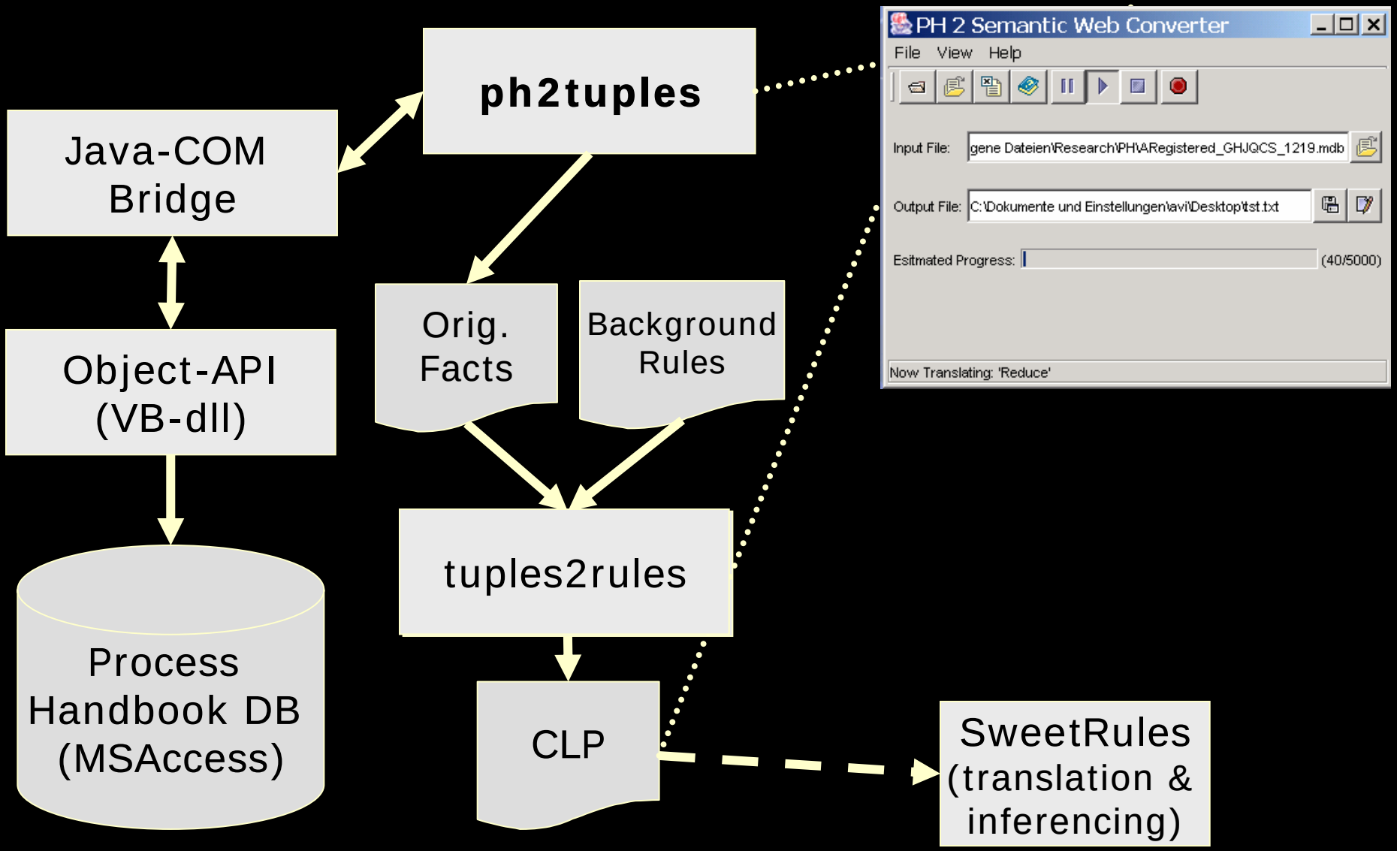


12/6/2005

Hurdles Encountered when Translating the Process Handbook

- Nonmonotonic
  - FOL (including OWL) cannot represent
- Inheritance semantics hidden in code
  - Need to rationally reconstruct
- Only derived assertions are saved
  - Need to reconstruct premises
- Concept of slotted predicates
  - Use n-tuples
- Class as instance
  - *In-progress: combining with class as predicate*

Translation Processing Architecture



Output Background rules

- ~ 50 Background rules in CLP (~80 OLP)
- Transitivity of subclasses
- Domain and range for properties
- Partial functionality of slotted properties
- Axiomatization of inheritance prioritization partial order
- Default inheritance for properties

Output

Partial Output on Process “Sell” I

```
/* Declare subtype relationship 'Sell_263900' of 'Exchange_74000' */
        subclassof('Sell_263900, 'Exchange_74000);

/* Declare type 'Sell_263900' */
        class('Sell_263900);

/* Declare subtype relationship 'Sell_263900' of 'activity' */
        subclassof('Sell_263900, 'activity);

/* New value for 'has_attribute' at entity: Sell_263900 and slot: ph_Description */
<lb4987>
        pr(la4987, 'Sell_263900, 'has_attribute, 'ph_Description, "Selling implies an exchange of
    value from the customer to the seller for a product and/or service._cr_nl_cr_nlNote that the
    subactivities in 'sell' are the converse of 'buy'.");

/* New value for 'has_attribute' at entity: Sell_263900 and slot: ph_Name */
<lb4997>
        pr(la4997, 'Sell_263900, 'has_attribute, 'ph_Name, "Sell");

/* New value for 'has_attribute' at entity: Sell_263900 and slot: ph_PIFID */
<lb5003>
        pr(la5003, 'Sell_263900, 'has_attribute, 'ph_PIFID, "960823131555AB2639");
```

Output: Partial Output on Process "Sell" II

```
/* New value for 'has_task' at entity: Sell_263900 and slot:
    960823131555AB2639SL1367 */
<lb5008>
        pr(la5008, 'Sell_263900, 'has_task, '960823131555AB2639SL1367,
    'Identify_potential_customers_53400);

/* New value for 'has_task' at entity: Sell_263900 and slot:
    960823131555AB2639SL1369 */
<lb5009>
        pr(la5009, 'Sell_263900, 'has_task, '960823131555AB2639SL1369,
    'Identify_potential_customers'_needs_328100);

/* New value for 'has_task' at entity: Sell_263900 and slot:
    960823131555AB2639SL1368 */
<lb5010>
        pr(la5010, 'Sell_263900, 'has_task, '960823131555AB2639SL1368,
    'Inform_potential_customers_98400);
```

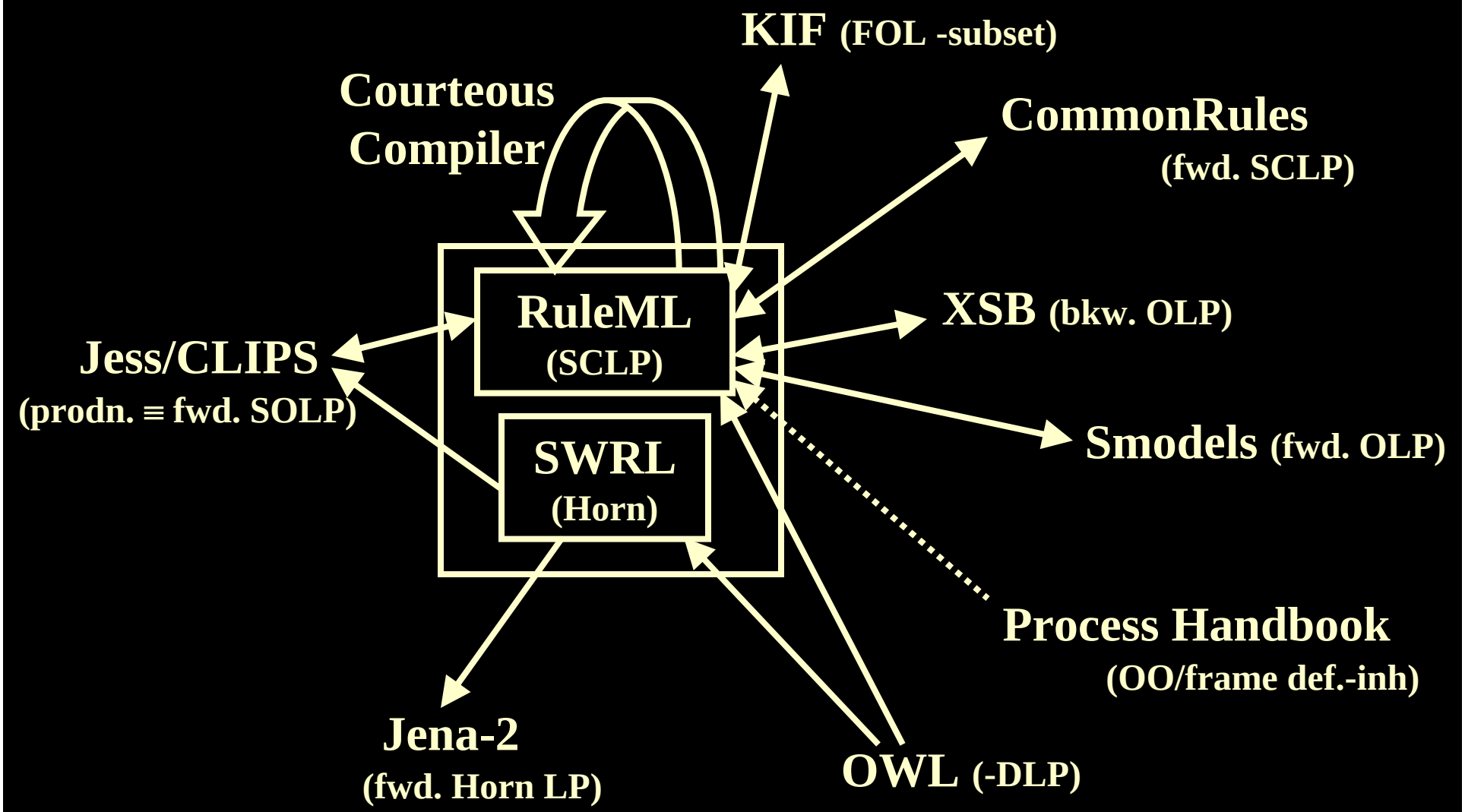
Output: Partial Output on Process "Sell" II

```
/* New value for 'has_task' at entity: Sell_263900 and slot: 960823131555AB2639SL1366 */
<lb5011>
        pr(la5011, 'Sell_263900, 'has_task, '960823131555AB2639SL1366,
    'Obtain_order_280400);

/* New value for 'has_task' at entity: Sell_263900 and slot: 960823131555AB2639SL1371 */
<lb5012>
        pr(la5012, 'Sell_263900, 'has_task, '960823131555AB2639SL1371,
    'Deliver_product_or_service_262300);

/* New value for 'has_task' at entity: Sell_263900 and slot: 960823131555AB2639SL1370 */
<lb5013>
        pr(la5013, 'Sell_263900, 'has_task, '960823131555AB2639SL1370,
    'Receive_payment_53800);

/* New value for 'has_task' at entity: Sell_263900 and slot: 960823131555AB2639SL3867 */
<lb5014>
        pr(la5014, 'Sell_263900, 'has_task, '960823131555AB2639SL3867,
    'Manage_customer_relationships_267400);
```

Sample Conclusion

```
/* Sell_by_mail_order has subactivity
   Deliver_product.

   This is inherited by default from Sell_Product.
 */
       h('Sell_by_mail_order,
          'has_task,
           960823131555AB2639SL1371,
           'Deliver_product).
```

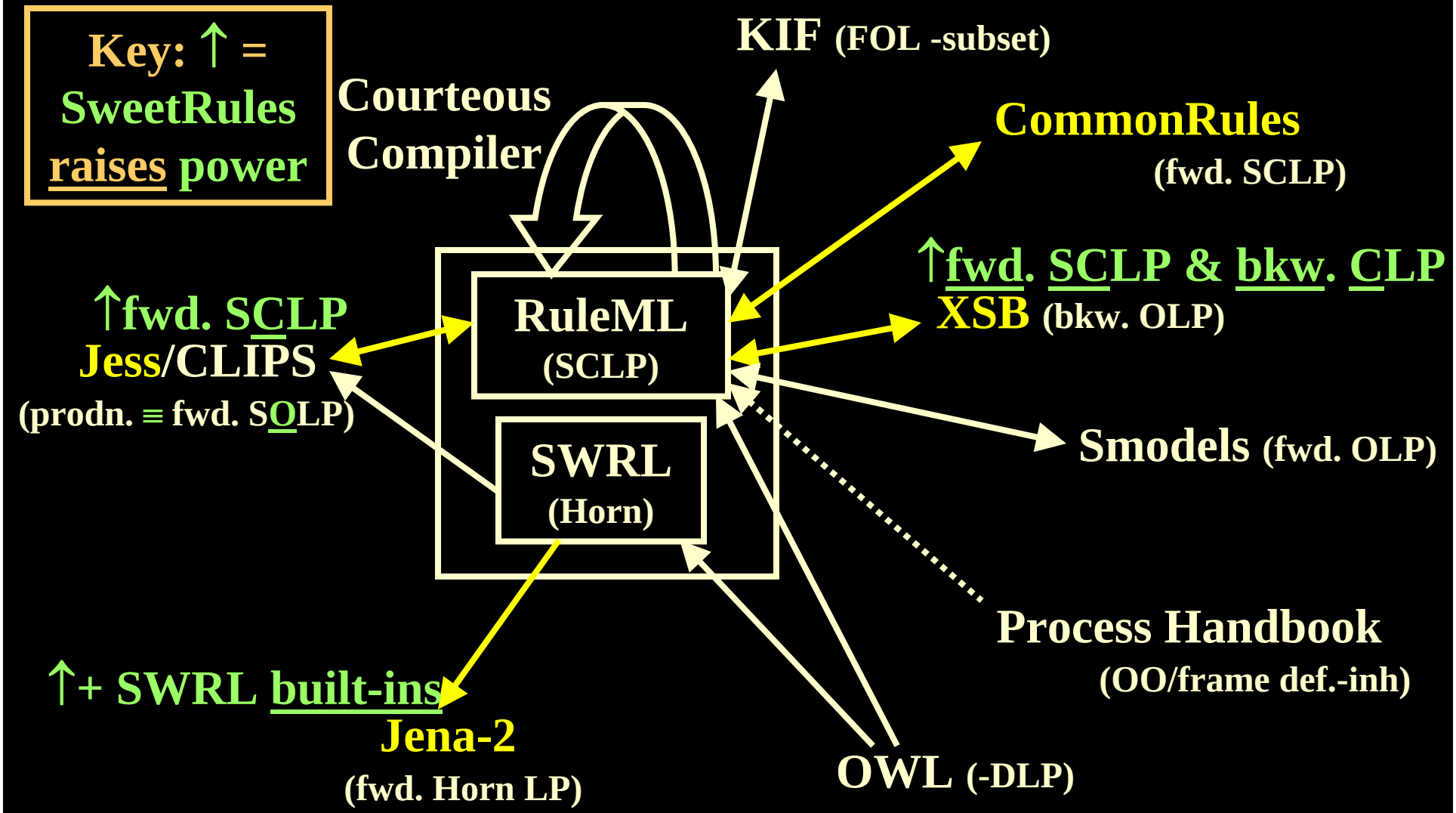
SweetRules Today: Translators Graph



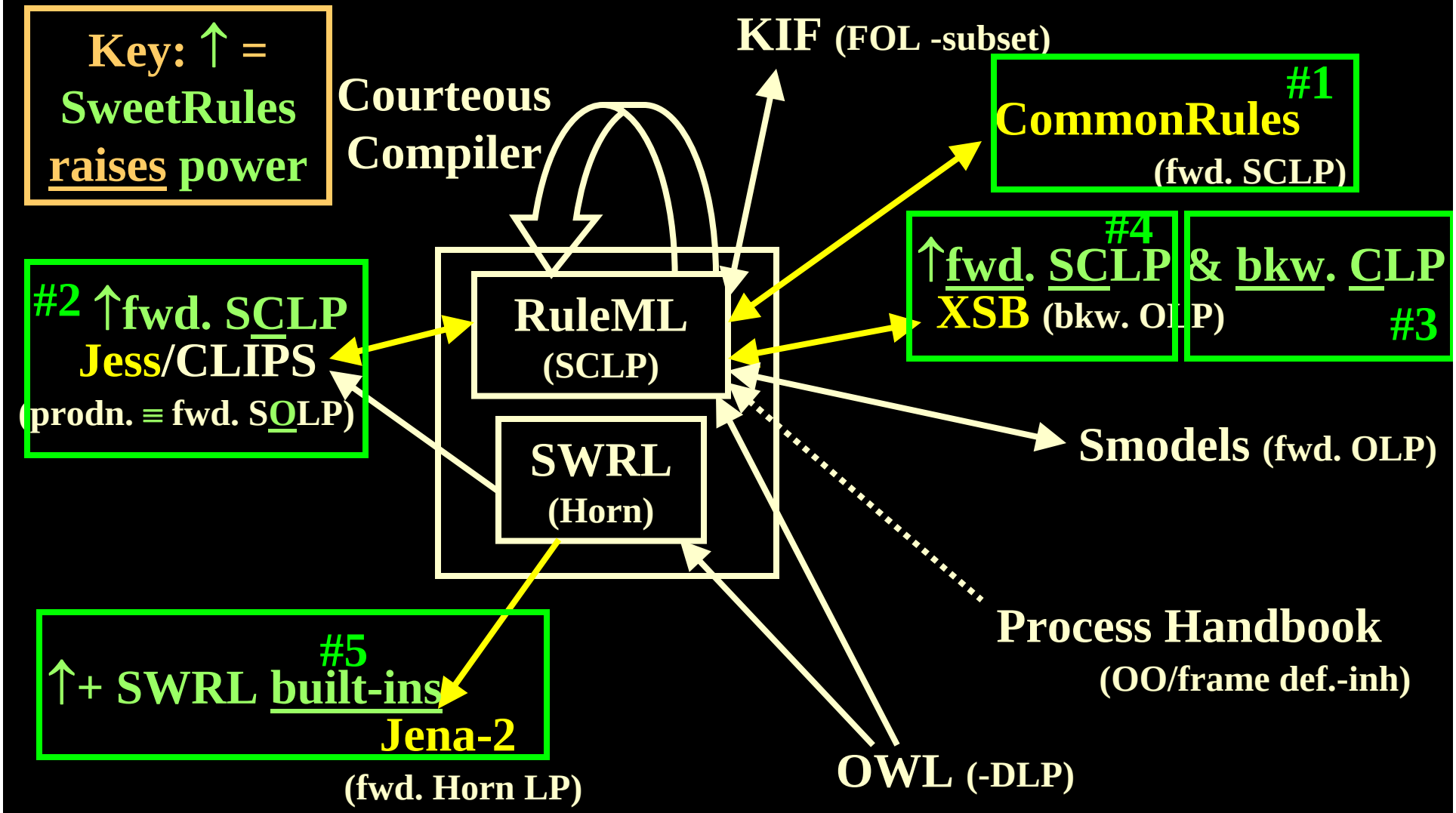
SweetRules Inferencing Capabilities Today: Overview

- Inferencing engines in RuleML/SWRL via translation:
  - Indirect inferencing:
    1. translate to another rule system, e.g., {XSB, Jess, CommonRules, or Jena}
    2. run inferencing in that system's engine
    3. translate back
  - Can use composite translators

SweetRules V2.0: Indirect Inferencing Engines



SweetRules V2.0 New Inferencing Engines



SweetRules Components Today

- Some components have distinct names (for packaging or historical reasons): E.g.,
  - SweetCR translation & inferencing RuleML ↔ CommonRules
  - SweetXSB translation & inferencing RuleML ↔ XSB
  - SweetJess translation & inferencing RuleML ↔ Jess
  - SweetOnto translation {RuleML, SWRL} ← OWL + RDF-facts
  - SweetJena translation & inferencing SWRL → Jena-2
- Other Project Components: (separate codebases for licensing or other reasons)
  - SWRL Built-Ins library *Currently:* for Jena-2
  - SweetPH translation RuleML ← Process Handbook (OO/frame ontologies)
    - *Currently V1.2 is running. Separately downloadable V2 is in progress.*
  - Protégé OWL Plug-in authoring SWRL rules (Horn, referencing OWL)
    - Enhancement providing SWRL Rules authoring is part of the Plug-In.
  - SWRL Validator