

# SILK: Rules, Semantic Web, and Databases Take a Leap in Scalable Logical Power

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\*\* <http://www.meetup.com/Semantically-Webbed-Seattle-Meetup-Group>



# Outline and Overview

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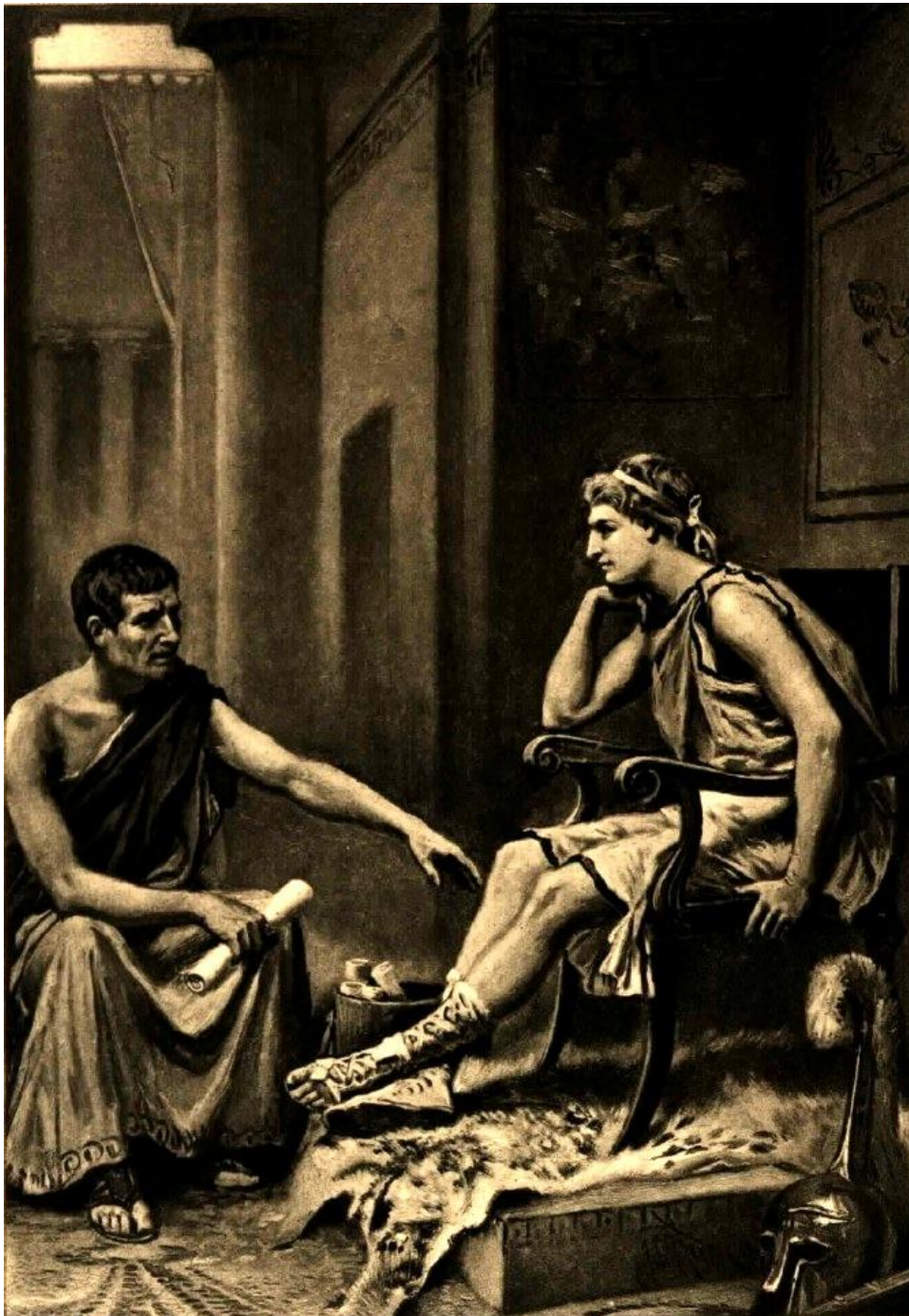
- **SILK research program within Vulcan's Project Halo**
  - Language and system for advanced knowledge representation (KR)
  - Digital Aristotle vision: question-answering for science
  - Scalability for social structured knowledge: entry, reuse, querying
- **SILK Language, Hyper Logic Programs KR, and RIF-SILK**
  - Expressive features: defaults, actions, higher-order, frames, webized, interchange
  - Advanced defaults: prioritized conflict handling, argumentation, omni-directional, tractability
- **SILK System**
  - Reasoning: layered architecture, transformations, tabling
  - Knowledge Acquisition (KA) and UI: interchange; editing, explanation
- **Potential application areas in business and government**
  - Horizontal: policies, workflows; ontology mapping, knowledge integration
  - Vertical: e-commerce, defense intelligence, trust, biomed, financial, mobile
- **Demo of default rules in SILK GUI: edit, query, explain**
- **Conclusions**
  - Higher-abstraction KR closer to human cognition and social pragmatics
  - Radically extends expressive power of SQL, RDF(S), SPARQL, OWL-RL, RIF-BLD
  - Remedies major limitations of semantic web's current KR foundation

# Vulcan's Project Halo

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- **Vision of Digital Aristotle: question-answering for science**
  - Put the bulk of the world's scientific and similar knowledge on-line
  - Answer questions, act as personal tutor, with deep reasoning
- **College-level science selected as initial domain focus**
  - Good metrics available: textbook-type exam Q's. Initial domain task focus is:
    - **Advanced Placement Exam (AP) in Biology, Physics, and Chemistry**
      - Taken by USA high-school students to get credit for 1<sup>st</sup>-year college courses
- **AURA AI expert system developed (2004-)**
  - Controlled Natural Language, GUI, Frame-based KR, Problem-Solving
  - Students as users – formulate questions, formulate knowledge
- **Semantic MediaWiki+ developed (2007-)**
  - Leading semantic wiki. Open-source. Simple rules, light ontologies.
- **SILK developed (2008-)**
  - Largest\* rule research program in USA. Multi-institutional: primarily via contractors.
    - A knowledge representation (KR) language and system (with reasoner, UI, interchange)





# Aristotle Tutoring Alexander

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# SILK Contributors current/past (partial list)

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# SILK's Goals

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- **Address fundamental requirements for scaling Semantic Web to widely-authored Very Large KBs in business and science that answer questions, proactively supply info, and reason powerfully**
- **Expressiveness + Semantics + Scalability**
  - Push the frontier. Language and system.
- **Better Knowledge Representation (KR)**
  - Expressive power: defeasibility, higher-order. E.g., causal processes in AP Biology.
  - Performance scalability of reasoning, including knowledge updates
- **More effective Knowledge Acquisition (KA)**
  - + By Subject Matter Experts (SMEs), not programmers or knowledge engineers
  - + Collaboratively – incorporate large #s of SMEs in KB construction & maintenance
    - + Leveraging the Web
- **Better KR also for sake of better KA**
  - Web knowledge interchange (with merging) for scalability of collaborative KA
  - The underlying KR is the target for KA: **“The KR is the deep UI”**
    - Understandability via semantics and expressiveness
  - Raise abstraction level closer to the user's natural language and cognition

# Expressiveness “Brittleness” Areas Targeted

- **Defaults/Exceptions/Defeasible** (*incl. nonmonotonic reasoning, theory revision, argumentation, truth maintenance*)
  - A kinematics problem situation has standard earth gravity, and no air resistance. [physics AP]
  - A given organism has the anatomy/behavior that is typical/normal for its species, e.g., a bat has 2 wings and flies. [bio AP]
  - Price info for an airplane ticket on Alaska Air’s website is accurate and up to date. [e-shopping]
  - ❖ **Practical reasoning almost always involves a potential for exceptions**
- **Hypotheticals**
  - If Apollo astronaut Joe golfed a ball on the moon, then standard earth gravity would not apply. [negative hypothetical] [*conflict* between defaults, resolved by *priority* among them]
  - If I had swerved my car 5 seconds later than I did, I would have hit the debris in the left lane with my tire. [*counterfactual*]
- **Actions and Causality**
  - If a doorkey is incompletely inserted into the keyhole, turning the key will fail. [*precondition*]
  - During the mitotic stage of prometaphase, a cell’s nuclear envelope fragments [biology AP]
  - After a customer submits an order on the website, Amazon will email a confirmation and ship the item. [Event-Condition-Action (ECA) rule] [policy]
- **Processes (i.e., representing and reasoning about processes)**
  - Mitosis has five stages; its successful completion results in two cells. [compose] [partial description]
  - If Amazon learns that it will take an unexpectedly long time to stock an ordered item, then it emails the customer and offers to cancel the order without penalty. [exception handling]
  - A Stillco sensor-based negative feedback thermal regulator is adequate to ensure the overnight vat fermentation of the apple mash will proceed within desired bounds of the alcohol concentration parameter. [science-based business process]

**Ubiquitous in science, commonsense, business, etc. All are interrelated.**

# *Concept of KR*

- A KR  $S$  is defined as a triple  $(LA, LC, |=)$ , where:
  - $LA$  is a formal language of sets of assertions (i.e., premise expressions)
  - $LC$  is a formal language of sets of conclusions (i.e., conclusion expressions)
    - *Remark: In LP KR, LC is not even a subset of LA!*
  - $|=$  is the entailment relation.
    - $\text{Conc}(A,S)$  stands for the set of conclusions that are entailed in KR  $S$  by a set of premises  $A$ 
      - We assume here that  $\text{Conc}$  is a functional relation.
- Typically, e.g., in FOL and LP, entailment is defined formally in terms of models, i.e., truth assignments that satisfy the premises and meet other criteria.



# Declarative Logic Programs (LP) is the Core KR in today's world ... including the Semantic Web

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- **LP is the core KR of structured knowledge management today**
  - **Databases**
    - Relational, semi-structured, RDF, XML, object-oriented
    - SQL, SPARQL, XQuery
    - Each fact, query, and view is essentially a rule
  - **Semantic Rules**
    - Rule Interchange Format (RIF): -BLD, -Core
    - RuleML standards design, including SWRL
  - **Semantic Ontologies**
    - RDF(S)
    - OWL-RL (= the Rules subset). E.g., Oracle's implementation of OWL.
- **The Semantic Web today is mainly based on LP KR**
  - ... and thus essentially equivalent to semantic rules
  - **You might not have realized that!**



# SILK's new KR: *Hyper* Logic Programs

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- **Extended LP that is the first to combine key advanced features**
- **Defaults + Higher-Order + External Actions/Events/Queries**
- **+ Webized, Frames, (clean) Negation and NAF, Equality, Functions, Skolems, Aggregates, Integrity Constraints, Lloyd-Topor, ...**
- **Tightly interoperates with very broad case of first order logic (FOL), too**
  - Any clause, not just Horn. Sound from FOL viewpoint.
- **Transforms knowledge from higher to lower abstraction levels**
  - Higher is good for KA; lower is good for reasoning (code reuse, optimization)
- **Tractable computationally – complexity is same as Horn LP**
  - Polynomial time -- similar to relational DBMS -- if there's no recursion thru functions
  - Retains pragmatic quality of LP: “intuitionistic” – lack general “reasoning by cases”
- **New approach to defaults**
  - *Argumentation theory*: ~20 “meta-” rules specify debate principles for defeat
  - Much more expressive: higher-order, equality, ...
  - Much easier to implement: ~20 rules instead of 1000's of lines of code
  - Much more efficient: eliminates expensive knowledge recompilation step
  - *Hyper rules*: omni-directional clauses, prioritized handling of multi-way conflicts

# SILK's KR Approach, continued

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- **KR Language**
  - Syntax: ASCII presentation syntax, abstract syntax, RIF dialect (RIF-SILK)
  - Semantics: model theory, proof theory. Closely related to the transformations (above).
- **Knowledge Interchange**
  - Via load, or query, or event. E.g., embed a SPARQL query in the body of a rule.
  - KR languages: SPARQL, RDF(S), SQL, ODBC; SILK, RIF, OWL(-RL), Cyc, AURA
- **Reasoning system**
  - Backward inferencing primarily -- i.e., query answering
  - Tabling saves and reuses computation from previous subqueries
    - Supports fast updating and forward inferencing
  - Good efficiency/scalability of performance
- **Synergizes 20 years of LP research progress**
  - Courteous defaults and external actions/queries cf. IBM Common Rules, SweetRules
  - Higher-order cf. HiLog, Common Logic
  - Negation-As-Failure cf. well founded
  - Performance optimizations from DBMS, Prolog, BRMS, AI
- **Extensive requirements analysis, use cases, benchmarking**

# Representational Uses for Defaults and Higher-Order

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## Defaults (cf. Courteous, with Prioritization)

- Negation
- Pragmatic knowledge/reasoning has potential for exceptions and revision
  - Learning and science: may falsify previous hypotheses after observation or communication
- Debate and trust: priorities from authority, reliability, recency
- Updating, merging, change: increase modularity/reuse in KA/KB lifecycle
- Process causality: persistence, indirect ramified effects, interference
- Hypotheticals, e.g., counterfactuals
- Inheritance: more-specific case overrides more-general case
- Policies, regulations, laws – the backbone of society and institutions
- Natural language understanding (NLU) aspects: e.g., co-reference

## Higher-Order (cf. Hilog and reification)

- Meta- knowledge and meta- reasoning, generally
- Ontology mapping, KB translation, KR macros, reflection, NLU aspects
- Provenance, multi-agent belief, modals, many aspects of context

# RIF-SILK Dialect

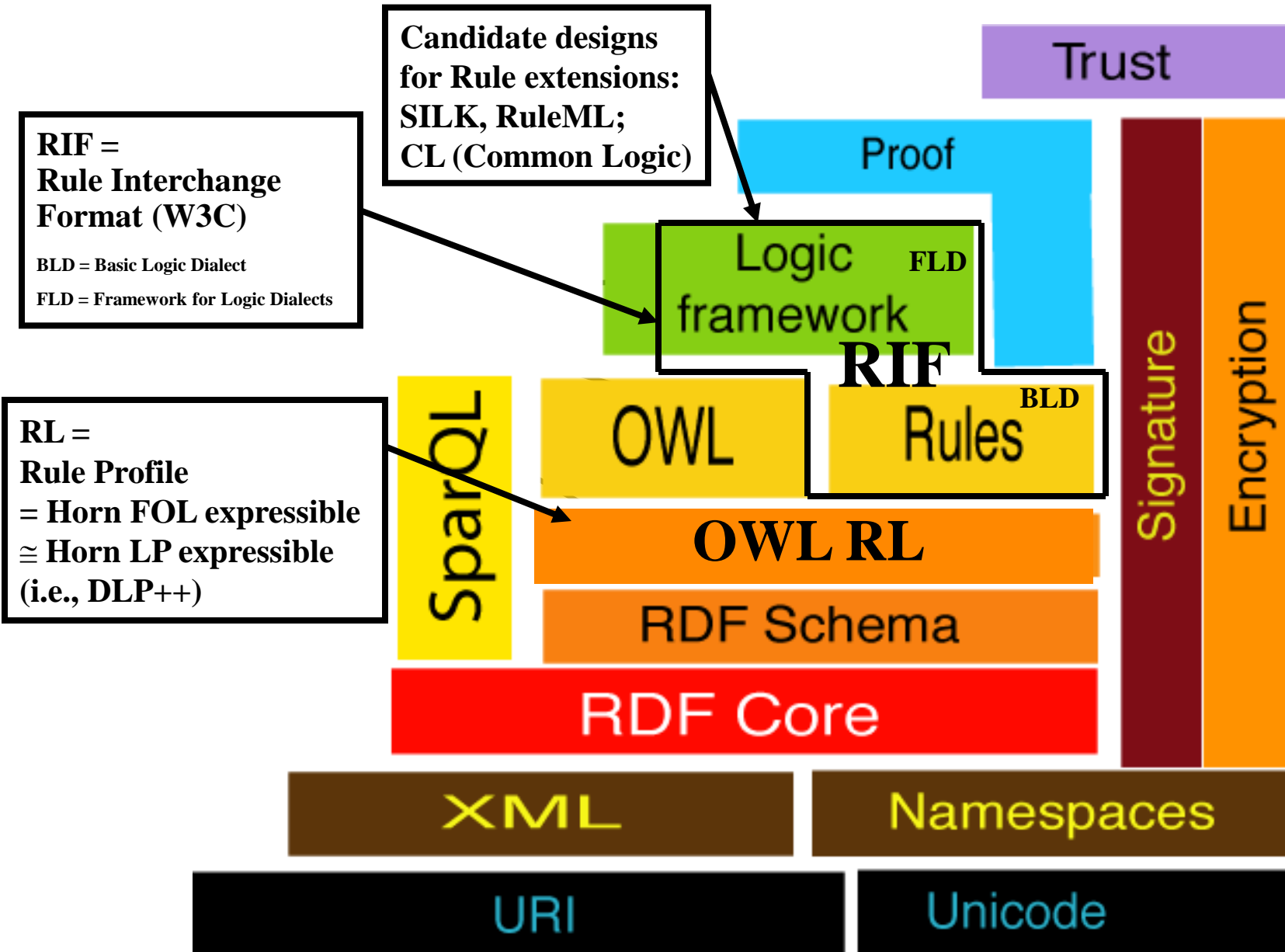
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- **It's expressively powerful RIF** (RIF = W3C Rule Interchange Format standard)
  - New dialect defined using RIF's Framework for Logic Dialects (FLD)
  - Extends (supersedes) RIF-BLD (Basic Logic Dialect) and RIF-Core
    - These are based essentially on Horn LP
  - Notably: adds defaults and external actions (side-effectful)
    - Needed for most of today's business applications of (non-semantic) rules
    - Retains "Grade AAA" semantics – model-theoretic
    - Retains computational scalability of Horn LP
- **Status**
  - Draft specification – public (initial version 12/2009, current 2/2010)
    - Semantics section is in progress (summarizes previous theory papers)
  - Implemented translator (bidirectional) is in current SILK system
  - Under discussion with W3C: role in next steps of RIF overall

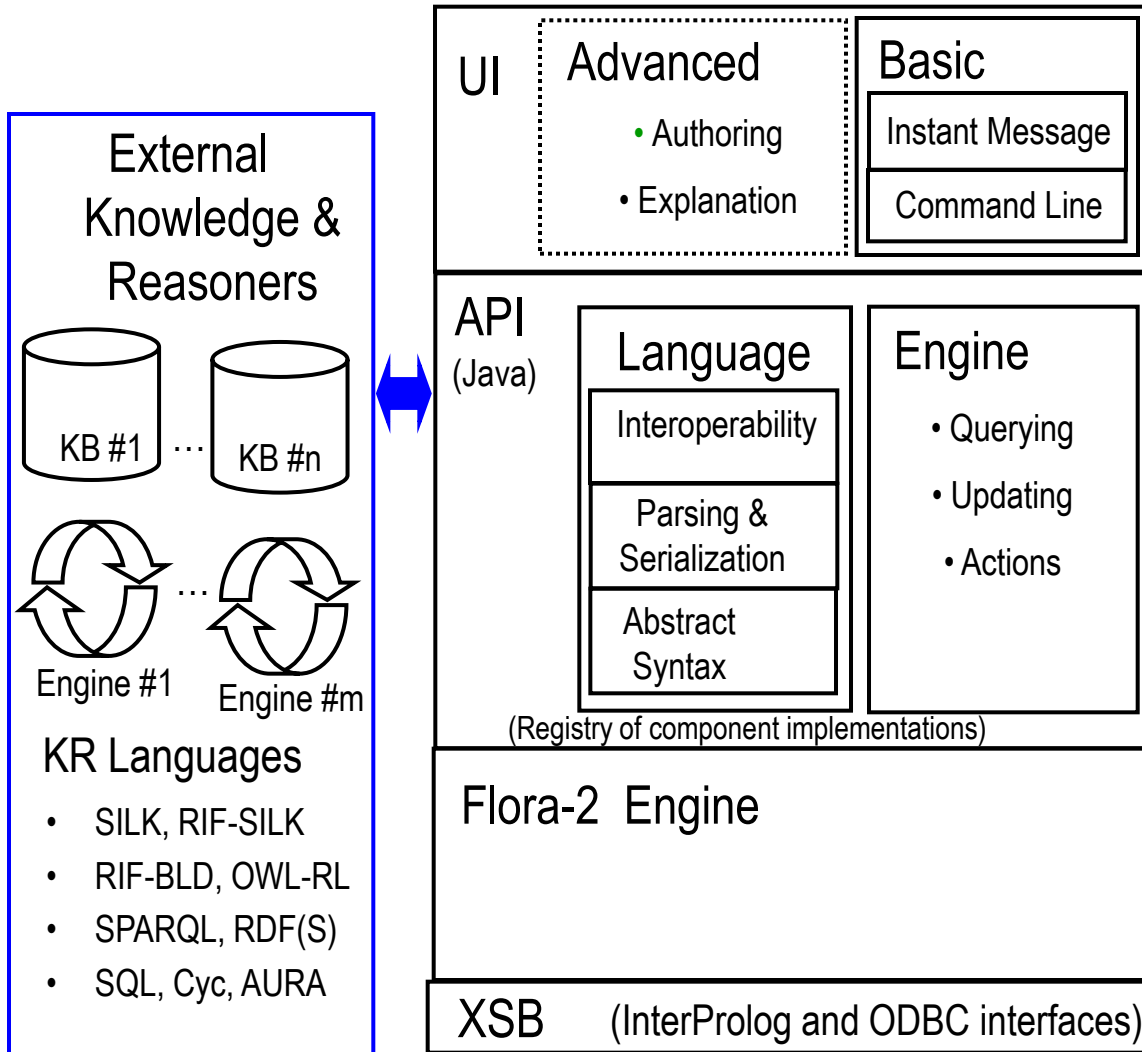
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- **SHOW briefly: RIF-SILK Dialect specification document**



# Updated: 06-2010 Semantic Web “Stack”



# SILK Architecture today (V2.2)



- API Functionality
  - Higher-order defaults reasoning, combines many other advanced KR features
  - SILK and external KR language support integrated tightly with reasoning engine
- UI Functionality
  - Graphical, tabular
  - For Knowledge Engineers
- *Future Items*
  - *UI: SME-friendlier, English (NL)*
  - *KR: probabilistic, parallelization, more interchange KRs*
- Test Sets Focus
  - Defaults, Process
  - AP esp. Biology

# Ecology Ex. of Causal Process Reasoning in SILK

```
/* Toxic discharge into a river causes fish die-off. */
/* Initial facts, and a constraint that fish count is unique */
@[strict] occupies(trout,Squamish);
@[strict] fishCount(0,Squamish,trout,400); // first argument is an integer time
@[strict] neg (fishCount(?s,?r,?f,?C1) and fishCount(?s,?r,?f,?C2) ) <== ?C1 != ?C2;
/* Action/event description that specifies causal change, i.e., effect on next state */
@[tag->tdf1] fishCount(?s+1,?r,?f,0)
                <== occurs(?s,toxicDischarge,?r) and occupies(?f,?r);
/* Persistence (“frame”) axiom */
@[tag->pef1] fishCount(?s+1,?r,?f,?p) <== fishCount(?s,?r,?f,?p);
/* Action effect axiom has higher priority than persistence axiom */
@[strict] silk:overrides(tdf1,pef1).
/* An action instance occurs */
@[id->UhOh, strict] occurs(1,toxicDischarge,Squamish).;
```

*As desired:* |= fishCount(1,Squamish,trout,400)

|= fishCount(2,Squamish,trout,0)

# E-Commerce Ex. of Causal Process Reasoning

*/\* E-commerce delivery logistics. \*/*

Overall quite similar to ecology ex.

*/\* Initial fact, and constraint that location is unique \*/*

@[strict] loc(0,PlasmaTV46,WH\_LasVegasNV); // first argument is an integer time

@[strict] neg(loc(?s,?item,?posn1) and loc(?s,?item,?posn2)) <== ?posn1 != ?posn2;

*/\* Action/event description that specifies causal change, i.e., effect on next state \*/*

@[tag->mov] loc(?s+1,?item,?addr) and neg loc(?s+1,?item,?warehouse)

<== shipment(?s,?item,?warehouse,?addr) and loc(?s,?item,?warehouse);

*/\* Persistence (“frame”) axioms about location \*/*

@[tag->peLoc] loc(?s+1,?item,?posn) <== loc(?s,?item,?posn);

@[tag->peLoc] neg loc(?s+1,?item,?posn) <== neg loc(?s,?item,?posn);

*/\* Action effect axiom has higher priority than the persistence axioms \*/*

silk:overrides(mov,peLoc)

*/\* An action instance occurs \*/*

@[id->deliv57, strict] shipment(1, PlasmaTV46, WH\_LasVegasNV, Nine\_Fog\_St\_SeattleWA);

*As desired:* |= loc(2, PlasmaTV46, Nine\_Fog\_St\_SeattleWA);

|= neg loc(2, PlasmaTV46, WH\_LasVegasNV);

# Complex AP Biology Examples

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- **Causal process reasoning is a large portion of AP Biology, often requiring multi-step causal chains and/or multiple grain sizes of description to answer a question.**
- **Several such complex examples drawn from exams or textbooks have been successfully represented in SILK. E.g.:**
  - "A researcher treats cells with a chemical that prevents DNA synthesis from starting. This treatment traps the cells in which part of the cell cycle?"  
The correct answer is: G1 [which is a sub-phase of interphase]
  - "In some organisms, mitosis occurs without cytokinesis occurring. This will result in:
    - a. cells with more than one nucleus
    - b. cells that are unusually small.
    - c. cells lacking nuclei.
    - d. destruction of chromosomes.
    - e. cell cycles lacking an S phase."The correct answer is: a. [two nuclei form in a cell, but no new cell wall splits the cell]
  - "Suppose the typical number of chromosomes in a human liver cell was 12. [Notice this is counterfactual; there are actually 46]. What would the typical number of chromosomes in a human sperm cell be?"  
The correct answer is: 6 [half of the number in the liver and most other organs]

# Trust Mgmt. Ex. of Higher-Order Defaults in SILK

illustrating also basic Knowledge-level Communication, and Frame syntax

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In Frame syntax: `subject[property -> object]` stands for `property(subject,object)`

*/\* Trust policy administration by multiple agents, about user permissions \*/*

*/\* Admin. Bob controls printing privileges including revocation (neg). \*/*

`Bob[controls -> print]. Bob[controls -> neg print];` */\* neg print means it's disallowed.\*/*

`Cara[controls -> ?priv];` */\* Cara is the most senior admin., so controls all privileges. \*/*

*/\* If an administrator controls a privilege and states at a time (t) that a user has a privilege, then the user is granted that privilege. Observe that ?priv is a higher-order variable. \*/*

`@[tag->grant(?t)] ?priv(?user) :- ?admin[states(?t) -> ?priv(?user)] and ?admin[controls(?priv)];`

*/\* More recent statements have higher priority, in case of conflict. \*/*

`silk:overrides(grant(?t2), grant(?t1)) <== ?t2 > ?t1 ;`

*/\* Admin.'s Bob and Cara make conflicting statements over time about Art's printing \*/*

`@[strict] Cara[states(2007) -> print(Art)] and Cara[states(2007) -> webPage(Art)] ;`

`Bob[states(2008) -> neg print(Art)] ;`

*As desired:* `|= neg print(Art) and webPage(Art).`

*/\* Currently, Art is permitted a webpage but not to print. \*/*



# Potential Applications in Business and Government

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- **Horizontal**

- Policies and policy-based workflows
  - Monitor, report, react, handle exceptions, execute, enforce, customize
  - Trust: confidentiality, authorization, compliance, governance
- Ontology mapping/mediation and knowledge integration
  - Perspective: the mappings themselves constitute ontological knowledge. E.g., a dictionary.

- **Vertical**

- E-commerce: shopping & advertising, contracts, customer care, catalogs
- Defense: intelligence, operations
- Financial: reporting, regulatory compliance
- Biomed: pharma, e-science, clinical records and guidance, insurance
- Mobile: personalize communication

- **Many use cases in RIF, RuleML, SWSL documents & prototypes**

- E.g., employ defaults or other features not yet well supported commercially

# DEMOS

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- **SHOW HERE: SemTech-2010 DEMO**
  - **Default rules in SILK GUI: edit, query, explain; exploiting omni-directionality**
    - Business policies about ad placements in news
- **Also: Demo'd at ISWC-2009 and RuleML-2009 conferences**
  - **Scenario of environmental watchdog group's monitoring workflow**
    - Recognize toxic discharge into Ohio River watershed from sharp decline in fish count
    - Alert news media, government agencies, citizens social network
  - **Reactive: standing queries trigger external actions upon update events**
  - **Load imported RDF(S) and RIF-BLD**
  - **Externally query SPARQL, and Excel via ODBC**
  - *This demo won an award at RuleML-2009, essentially for best system*
- **Aim to make videos of demos and post on SILK website.**
  - *Some already there*

# Remedying FOL Semantics' Lack of Scalability

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- **Hyper LP handles conflict robustly – get consistent conclusions**
  - **Whereas FOL is a “Bubble” – it’s perfectly brittle semantically in face of contradictions from quality problems or merging conflicts.**
    - Any contradiction is totally contagious – the conclusions all become garbage
  - E.g., OWL beyond the RL subset suffers this problem. So does Common Logic. (Technically, RIF-BLD and RDF(S) are defined via FOL semantics too, although their typical implementations are essentially LP. )**

**A KB with a million or billion axioms formed by merging from multiple Web sources, is unlikely to have zero KB/KA conflicts from:**

- Human knowledge entry/editing
  - Implicit context, cross-source ontology interpretation
  - Updating cross-source
  - Source trustworthiness
- ***Hyper LP’s approach provides a critical advantage for KB scalability***
    - ***semantically, as well as computationally***

# FOL: A Bubble

Extreme sensitivity to conflict limits its scalability in # of axioms and # of merges



Left:

<http://www.dailymail.co.uk/sciencetech/article-1199149/Super-slow-motion-pictures-soap-bubble-bursting-stunning-detail.html>

Above:

[http://img.dailymail.co.uk/i/pix/2007/11\\_03/BubblePA\\_468x585.jpg](http://img.dailymail.co.uk/i/pix/2007/11_03/BubblePA_468x585.jpg)

# Conclusions

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- **Radically extends the KR power of W3C OWL, SPARQL, RIF-BLD – and of SQL**
  - Defaults and robust conflict handling – *cope with knowledge quality and context*
  - Higher-order and flexible meta-reasoning – *elevate meta-data to meta-knowledge*
  - Actions and events, cf. production rules and process models – *activate knowledge*
- **Raises the KR abstraction level for business users (SMEs) and NL KA/UI**
- **Use cases in biomed, business policies, ontology mapping, e-commerce, ...**
- **Redefining the KR playing field for Semantic Web, business rules, and rule-based process management**
  - Defaults and Higher-Order – yet retain computational web scalability
  - Escape from FOL Bubble– yet retain grade-AAA model-theoretic semantics
- **Motto: “Transforming Knowledge”**
  - Composes a set of KR transformations for ...
    - Expressive extensions – language and semantics
    - Translations between KR/syntaxes, for interchange
    - Reuse of previous algorithms and implementations



# Acknowledgements

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- **SILK contributors**
  - (previously listed)
- **Other contributors to several key previous KR efforts**
  - RuleML and SWSL (Semantic Web Services Language) standards designs
    - Notably: Harold Boley and Said Tabet
  - SweetRules and Flora-2 systems
    - Notably: Guizhen Yang



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# ***SILK – Transforming Knowledge***

# **Thank You**



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***OPTIONAL SLIDES FOLLOW***

# SILK's ambitious Vision for longer-term Impact

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- Key Knowledge Representation (KR) infrastructure sufficient to enable creation of global, widely-authored, very large knowledge bases (VLKBs) about science and business\*  
that answer questions  
and proactively supply information,  
using powerful reasoning about rules and processes,  
that can be customized in their content and actions  
for individual organizations or people
- Newest part of Vulcan's Project Halo  
which addresses the problems of **scale** and **brittleness** in KBs,  
including the Knowledge Acquisition and UI aspects

\* "Business" here is shorthand for human affairs, incl. government

# Sem Tech Industry Requirements targeted by SILK

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- **Need to raise abstraction level, e.g., for SME and NL KA/UI**
  - (SME = Subject Matter Expert, a.k.a. Business User)
- **Need robustness & meta-reasoning for web KB integration**
  - Cope with conflict, mediation, context, knowledge quality
  - Defaults  $\Rightarrow$  robustness, modularity  $\Rightarrow$  scalability
  - Higher-order  $\Rightarrow$  puts the meta- deeply in knowledge not just data
- **Hope: be like advance of the Relational model in DBMS**
  - Will Hyper LP be to the 2010s what Relational was to 1970s-80s?
    - (NB: software industry clockspeed was slower back then)

# Semantic Rules KR: Features Comparison

Level ("generation")	Groups of features	<i>SILK V1</i>	<i>Flora</i>	<i>RIF-BLD</i>
1G. Basic	ie: Horn, chaining, external queries, built-ins <i>(Level Summary)</i>	Y	Y	Y
2G. Advanced	<i>(Level Summary)</i>	<b>Most!</b>	lots	some
	Equality (derived via non-fact rules)	Y	Y	Y
	Functions	Y	Y	Y
	Convenience Package: Frames, integrity constraints, skolemization	Y	Y	R. frames
	Closed-World: unstratified NAF, aggregates, Lloyd-Topor	Y	Y	N
	Higher-Order (incl. reification)	Y	Y	N
	<b>Actions (external)</b> (via procedural attachments)	Developing	N	N
	Base Defaults (prioritized, cf. Courteous)	Y	N	N
	Webized syntax (URI names and XML/RDF KBs)	Developing	N	Y
3G. Hyper	<i>(Level Summary)</i>	<b>Pioneer!</b>	N	N
	<b>Higher-Order Defaults</b>	Y	N	N
	<b>Weakened Classical</b> (sound interchange with default rules)	Developing	N	N
<u>Other Misc.</u>		(NA)	(NA)	(NA)
	Other Expressive	Developing	R. inherit.	-
	Reasoner Efficiency (upper-tier on OpenRuleBench)	good	good	NA (standard)

- Summarizes detailed analysis of 40 KR expressive features, 17 systems.
- Notes: R. = Restricted; RIF-BLD = W3C Rule Interchange Format - Basic Logic Dialect.

# Features Comparison – More Systems & Stds

Level	Groups of Features	<i>SILK1</i>	<i>Flora</i>	<i>RIF-BLD</i>	<i>Jena</i>	<i>Onto-broker</i>	<i>Jess</i>	<i>IBM C.R.</i>	<i>DLV</i>	<i>SQL</i>	<i>SPA-RQL</i>	<i>Common Logic</i>	<i>OWL2 RL</i>	<i>OWL2 DL</i>
Basic	Horn chain. etc.	Y	Y	Y	Y	Y	Y	Y	Y	R.	R.	Y	R.	R.
Advanced	<i>(Level summary)</i>	<b>Most!</b>	lots	some	some	some	some	some	some	some	some	some	some	some
	Equality	Y	Y	Y	R.	R.	R.	N	Y	R.	R.	Y	R.	Y
	Functions	Y	Y	Y	N	N	N	Y	Y	N	N	Y	N	N
	Frames etc.	Y	Y	R.	R.	R.	R.	R.	R.	R.	R.	R.	R.	R.
	Closed-World	Y	Y	N	N	Y	R.	R.	most	R.	R.	N	N	N
	Higher-Order	Y	Y	N	N	N	R.	N	N	R.	R.	Y	R. bit	R. bit
	<b>Actions</b>	Dev.	N	N	N	N	Y	Y	N	N	N	N	N	N
	Base Defaults	Y	N	N	N	N	N	Y	N	N	N	N	N	N
	Webized	Dev.	R.	Y	Y	R.	R.	R.	R.	N	Y	Y	Y	Y
Hyper	<i>(Level summary)</i>	<b>1st!</b>	N	N	N	N	N	N	N	N	N	N	N	N
	<b>H-O. Defaults</b>	Y	N	N	N	N	N	N	N	N	N	N	N	N
	<b>Weak. Classi.</b>	Dev.	N	N	N	N	N	N	N	N	N	N	N	N
<u>Misc.</u>		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Other Expres.	Dev.	inherit.	-	-	-	events	-	disju.	R.	R.	classical	-	classic.
	Efficiency	good	good	NA	fair	good	fair	poor	good	NA	NA	NA	NA	NA

■ Summarizes detailed analysis of 40 KR expressive features, 17 systems.

■ Notes: Dev. = Developing, R. = Restricted; C.R.=Common Rules; disju.=disjunctive.

# Features Comparison – More Systems & Stds

Level	Groups of Features	<i>SILK1</i>	<i>Flora</i>	<i>RIF-BLD</i>	<i>Jena</i>	<i>Onto-broker</i>	<i>Jess</i>	<i>IBM C.R.</i>	<i>DLV</i>	<i>SQL</i>	<i>SPA-RQL</i>	<i>Common Logic</i>	<i>OWL2 RL</i>	<i>OWL2 DL</i>
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Basic	Horn chain. etc.
Advanced	<i>(Level summary)</i>
	Equality
	Functions
	Frames etc.
	Closed-World
	Higher-Order
Hyper	<b>Actions</b>
	Base Defaults
	Webized
	<i>(Level summary)</i>
Misc.	<b>H-O. Defaults</b>
	<b>Weak. Classi.</b>
	Other Expres.
	Efficiency

## Background on Systems and Standards:

- Jess is a representative commercial production rule (PR) system. PR was shown 5-7 years ago to have a semantic subset (based on the SweetRules translation). The currently most commercially important business rule management systems (BRMS) are based on PR or similar event-condition (ECA) action rules.
- W3C Rule Interchange Format (RIF)'s Basic Logic Dialect (BLD) is its main semantic part. There is also a framework for extensions. RIF is based primarily on RuleML, except for RIF's Production Rule Dialect (PRD).
- W3C OWL 2 RL is OWL's Rules subset (based on Description LP).
- Jena is a popular open-source semantic web toolkit, incl. for rules.
- Ontobroker is a commercial forward-chaining LP system.
- IBM Common Rules (C.R.) introduced the base defaults feature.
- Common Logic (CL) is an ISO standard for classical logic, used also by OMG's Semantic Business Vocabulary and Rules (SBVR) standard.
- DLV is a disjunctive LP system, by Univ. of Calabria (it has OR in rule heads)



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# ***SILK – Transforming Knowledge***

# **Thank You**



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# ***END OPTIONAL SLIDES***