Hyper Logic Programs in SILK
For Business and Science:
An Overview

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July 16, 2009
25-minute presentation at CULP 2009**

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** Workshop on Commercial Users of Logic Programming, co-located with the 25th
International Conference on Logic Programming (ICLP-2009), Pasadena, California
Outline of Talk

• Intro to the SILK effort, and its parent Project Halo

• Hyper Logic Programs KR approach and expressive features
  • Higher-Order Defaults
  • Examples and Use Cases
  • Remedying FOL Semantics’ Lack of Scalability
  • Comparison to other semantic rule systems and standards
    • RIF, BRMS, OWL, DBMS, etc.

• Conclusions and Directions
  • How You can be Involved
SILK’s ambitious Vision for longer-term Impact

• 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
SILK Effort

- **SILK = Semantic Inferencing on Large Knowledge**
  - What the next generation Web will be spun from

- A KR Language and KR System with reasoner, UI, interchange

- **Goal: Expressiveness + Semantics + Scalability + Web**

- **Began in 2008**
  - Part of Halo Advanced Research (HalAR), the new half of Project Halo

- **Largest rule research program in the US** (that we’re aware of)
  - Primarily via contractors
SILK Contributors current/past (partial list)

• Vulcan (Benjamin Grosof, Mark Greaves, Dave Gunning)
• Stony Brook University (Michael Kifer; students H. Wan, S. Liang, P. Fodor)
• SRI International (Vinay Chaudhri, David Martin, Ken Murray, Bill Jarrold)
• BBN Technologies (Mike Dean, Dave Kolas, Matt Rubin)
• Ontoprise GmbH (Daniel Hansch, Jurgen Angele)
• Automata (Paul Haley)
• Boeing (Peter Clark)
• Cycorp (Keith Goolsbey, Doug Lenat, Ben Rode)
• University of Texas (Bruce Porter, Ken Barker)
• University of Toronto (Sheila McIlraith; students S. Sohrabi, H. Ghaderi)
• University of Amsterdam (Bert Bredeweg)
• University of Freiburg (Georg Lausen)
• University of Michigan (Michael Wellman)
• Richard Fikes, consultant (Stanford University)
• Raphael Volz, consultant
Vulcan’s Project Halo; 1st system is AURA

- **Vision of Digital Aristotle**
  - Put the bulk of the world’s scientific and similar knowledge on-line
  - Answer questions, act as personal tutor, with deep reasoning

- **How to operationalize Digital Aristotle as a research effort?**

- **College-level science selected as initial domain focus**
  - Medium wide, medium deep.
  - Good metrics available: textbook-type exam Q’s. Initial domain task focus is:
    - Advanced Placement Exam (AP) in Physics, Chemistry, and Biology
      - Taken by USA high-school students to get credit for 1st-year college courses

- **AURA expert system developed** (see [http://www.ai.sri.com/project/aura](http://www.ai.sri.com/project/aura))
  - Novel combination of available techniques from AI
  - Controlled Natural Language, GUI, Frame-based KR, Problem-Solving
  - Students as users – formulate questions, formulate knowledge
  - Initial version 2004, then refined extensively and tested rigorously
Aristotle Tutoring Alexander

Halo Enters Semantic Web Era; 2nd system is SMW+

• **How to enable 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

• **Halo Extension to Semantic MediaWiki (SMW+) developed.**
  - Open source extension of the MediaWiki software Wikipedia runs on
  - Supports RDF and OWL subset, interleaved tightly with hypertext
  - Rapid maturation of initial functionality
  - Upcoming release: simple semantic rules (Horn) and access control
  - Strong community uptake, early commercial adoption already
  - For more, see [http://wiki.ontoprise.de](http://wiki.ontoprise.de)

• **But need better KR too, in part for sake of KA.**
  - The underlying KR is the target for KA: “The KR is the deep UI”
  - Web knowledge interchange (with merging) for scalability of collaborative KA
Goals for SILK KR Effort – Halo’s 3rd system

- **Expressiveness + Semantics + Scalability**
  - Push the Frontier: high risk, high return

- **Address requirements for AURA on AP task (and for SMW+)**
  - Expressive power (e.g., defaults and processes)
  - Understandability via semantics and expressiveness
    - Raise abstraction level closer to the user’s natural language and cognition

- **Address requirements for long-term Digital Aristotle vision**
  - Wider set of domains and tasks, via KR expressiveness and better KA
  - Knowledge interchange via semantics and expressiveness
  - Performance scalability of reasoning (incl. truth maintenance)
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.
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SILK’s New KR: **Hyper Logic Programs**

- Hyper Logic Programs KR combines new features
  - **Defaults** and Weakened Classical, cf. generalized Courteous LP
    - Higher-order defaults with priorities, cancellation, contraposition, multi-way conflicts
    - Sound interchange with classical logic (via hypermonotonic mapping)
  - **External Actions, Events, & Queries**, cf. generalized Production LP
    - Via procedural attachments. Including built-ins.
    - Enables interoperation with Production/ECA rules (via SweetRules technique)
    - Brings Actions (and events) to the semantic party

**with previous advanced features**

- Higher-order and Frames, cf. HiLog and F-Logic
- Webized syntax and Knowledge Interchange, cf. RIF/RuleML and OWL/RDF
- Closed-World, cf. well-founded unstratified NAF
- Good Efficiency of reasoner performance. With persistency & truth maintenance.
- Equality, Lloyd-Topor, Aggregation, Functions, Skolemization, Integrity Constraints
SILK – Summary

• Status: prototype engine, language, and theory for expressive heart
  • V1 adds Higher-Order Defaults to Flora
  • Extensive requirements analysis, use cases, benchmarking; ReCyc translation
  • V2 in development: adds Java API, Actions/Events, Interchange with RIF and Classical, …

• Radically extends the KR power of W3C OWL, SPARQL, and RIF – 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 business policies, ontology mapping, e-commerce, biomed, …

• 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’s Extreme Brittleness – yet retain grade-AAA model-theoretic semantics
More Rationale about Hyper LP KR

• Give up reasoning by cases
  • Source of exponential worst-case complexity in classical, disjunctive LP, stable LP
  • Can hope to reintroduce in restricted or altered form, or develop work-arounds, later
  • But there are many apps not requiring it, e.g., DBMS, BRMS

• Can realistically hope to be web-scalable performance-wise, unlike highly expressive classical
  • Polynomial computational complexity, under non-onerous restrictions
    • Same complexity as Horn rules!! (Must be careful of recursion through functions.)
  • Many optimizations available
  • Established track record of high scalability for relational databases
New Theory & Algorithms for Higher-Order Defaults

- Combines Courteous + Hilog, and generalizes

- **New approach to defaults: “argumentation theories”**
  - Meta-rules specify when rules are defeated
  - [Wan, Grosof, Kifer, et al. ICLP-2009]

- Extends straightforwardly to combine with other key features
  - E.g., Frame syntax, external Actions

- **Significantly improves on previous Courteous approach in other ways**
  - Eliminates a complex transformation
  - Much simpler to implement
    - 20-30 background rules instead of 1000’s of lines of code
  - Much faster when updating the premises
  - More flexible control of edge-case behaviors
  - Much simpler to analyze theoretically
SILK Current Status – More

• **New approach to representing causal change in processes**
  - Uses defaults

• **Use cases, incl. survey**
  - Science AP
  - Business domains

• **ReCyc**: Rough prototype translator from Cyc to SILK
  - 3 Million axioms from ResearchCyc (translates 99% of the KB)

• **Benchmarking of relevant rule systems**
  - OpenRuleBench [Liang et al. WWW-2009]

• **SILK V2 is in development. Near term steps include:**
  - Add expressive features, e.g., Weakened Classical, external Actions
  - Webize more fully, e.g., knowledge interchange, UI
Ecology Ex. of Causal Process Reasoning in SILK

/* Toxic discharge into a river causes fish die-off. */
/* Init. facts, and an “exclusion” constraint that fish count has a unique value */
occupies(trout,Squamish).
fishCount(s0,Squamish,trout,400).
!- 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 */
@tdf1 fishCount(?s+1,?r,?f,0) :- occurs(?s,toxicDischarge,?r) and occupies(?f,?r).
/* Persistence (“frame”) axiom */
@pef1 fishCount(?s+1,?r,?f,?p) :- fishCount(?s,?r,?f,?p).
/* Action effect axiom has higher priority than persistence axiom */
@pr1 overrides(tdf1,pef1).
/* An action instance occurs */
@UhOh occurs(s0+1,toxicDischarge,Squamish).

As desired: |= fishCount(s0+1,Squamish,trout,400) and
fishCount(s0+2,Squamish,trout,0).

Notes: @ prefixes a rule label. ? prefixes a variable. :- means if. !- prefixes an exclusion, and means “it’s a conflict if”. In an exclusion, | means given that.
E-Commerce Ex. of Causal Process Reas. in SILK

/* E-commerce delivery logistics. */
/* Initial fact, and prevention constraint that location is unique */
loc(s0, PlasmaTV46, LasVegasWH).
!- loc(?s, ?item, ?posn1) and loc(?s, ?item, ?posn2) | ?posn1 != ?posn2.
/* Action/event description that specifies causal change, i.e., effect on next state */
@mov1 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 */
@pel1 loc(?s+1, ?item, ?posn) :- loc(?s, ?item, ?posn).
@pel2 neg loc(?s+1, ?item, ?posn) :- neg loc(?s, ?item, ?posn).
/* Action effect axiom has higher priority than the persistence axioms */
overrides(mov1, pel1). overrides(mov1, pel2).
/* An action instance occurs */
@deliv57 shipment(s0+1, PlasmaTV46, WH_LasVegasNV, 9_Fog_St_SeaattleWA).

As desired: |= loc(s0+2, PlasmaTV46, 9_Fog_St_SeaattleWA) and
    neg loc (s0+2, PlasmaTV46, WH_LasVegasNV).

Notes: @ prefixes a rule label. ? prefixes a variable. :- means if. !- prefixes an
exclusion, and means “it’s a conflict if”. In an exclusion, | means given that.
Trust Mgmt. Ex. of Higher-Order Defaults in SILK

illustrating also basic Knowledge-level Communication, and Frame syntax

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. */
@grant(?t) ?priv(?user) :- ?admin[states(?t) -> ?priv(?user)] and ?admin[controls(?priv)].
/* More recent statements have higher priority, in case of conflict. */
overrides(grant(?t2), grant(?t1)) :- ?t2 > ?t1.
/* Admin.’s Bob and Cara make conflicting statements over time about Al’s printing */
Bob[states(2008) -> neg print(Al)].

As desired: |= neg print(Al). webPage(Al).
/* Currently, Al is permitted a webpage but not to print. */

Notes: @ prefixes a rule label. ? prefixes a variable. :- means if. !- prefixes an exclusion, and means “it’s a conflict if”. In an exclusion, | means given that.
Use Cases for SILK beyond commercial state of art

- There are many!

- Existing use cases from SILK’s research-y or standards-design roots
  - E.g., from RIF, RuleML, SWSL documents and prototypes
  - E-commerce, financial, health, trust, SOA, policies, regulations, mobile, biomed, defense, etc.
  - Many of these are not yet implementable in current well-supported, well-performing commercially deployed systems
    - E.g., they use defaults
    - E.g., they use feature combinations that are not easily available
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Remedying FOL Semantics’ Lack of Scalability

- **Hyper LP handles conflict robustly**
  - Whereas FOL is a “Glass Bubble” – it’s perfectly brittle semantically in face of contradictions from . . .
  - Quality problems/errors in the data and knowledge
  - Conflict when merging KBs
    
    E.g., OWL beyond the RL subset suffers this problem

A VLKB 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

- **Weakening provides a critical advantage for VLKB scalability**
  - semantically, as well as computationally
FOL: A Glass Bubble

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

Keijo Kopra from Finland as he competes in the Iittala Cup glass-blowing competition June 7, 2008. (Reuters)
## Features Comparison – More Systems & Stds

<table>
<thead>
<tr>
<th>Level</th>
<th>Groups of Features</th>
<th>SILK1</th>
<th>Flora</th>
<th>RIF-BLD</th>
<th>Jena</th>
<th>Onto-broker</th>
<th>Jess</th>
<th>IBM C.R.</th>
<th>DLV</th>
<th>SQL</th>
<th>SPA-RQL</th>
<th>Common Logic</th>
<th>OWL2 RL</th>
<th>OWL2 DL</th>
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- **Summarizes detailed analysis of 40 KR expressive features, 17 systems.**
- **Notes:** Dev. = Developing, R. = Restricted; C.R.=Common Rules; disju.=disjunctive.
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Future Directions for SILK

• Process – more complex
• Natural Language KA and UI
• Parallelism in reasoning
• Connectors to Semantic Web, legacy BRMS and DBMS
• Uncertainty, Disjunction

• And Use Cases, of course

• Halo is part of an increasingly-integrated strategy at Vulcan to invest in semantics and advanced knowledge tools
  • Other investments: Radar Networks, ZoomInfo, Evri, etc.
  • Semantic MediaWiki+ is an early spinout
Impact Opportunities for SILK and HalAR

- **Improve by orders of magnitude:**
  - Scale of practical semantic default+actions reasoning
    - \( \leq 1000 \text{ rules} \Rightarrow \approx 100,000+ \text{ rules} \)
  - **Collaboration costs of multifold KB merging** when there’s conflict (as is usual)
    - Can take human out of the loop at run time
  - Population of users capable of specifying semantic rules
    - “KR Power to the People!” Leverage Aura and SMW+ KA/UI front-ends.

- **Synergize best of last 20 years of pure-research progress in LP KR**
  - \( \Rightarrow \) Redefine KR playing field of semantic web, business rules, & process management

- **Provide a key missing research piece for SOA / web services**
  - Enable building shared business/govt KBs on processes & policies \( \Rightarrow \) virtuous circle

- **Hope: be like advance of the Relational model in DBMS**
  - Will Hyper LP be to the 2010s what Relational was to 1970s-80s?

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**Key KR infrastruct. for widely-authored VLKBs for science and business**

that answer questions, proactively supply information, and reason powerfully
How You can be Involved

• **General Contact:** Benjamin Grosof  benjaming@vulcan.com
  • Suggest design, use cases, experts, cooperations

• **Visit the SILK webpage and sign up for the mailing list so you’ll be alerted of announcements about SILK**
  • URL: http://silk.semwebcentral.org
  • Mailing list: silk-announce@semwebcentral.org (very low volume)

• **Provide comments on SILK language design**
  • Initial public draft in ~ fall 2009
  • Plan to propose a RIF extension with defaults and actions
    • Corresponding to a large expressive subset of SILK

• **Try out SILK software**
  • Prototype, free for research use
  • V1 public release in ~ fall 2009; V2 in 2010; selected earlier users sooner

  • Also SMW+ upcoming release will have simple semantic LP rules of SILK-y flavor
    • In ~ fall 2009. Limited to Horn.
Acknowledgements

• **SILK contributors**
  • (previously listed)

• **Contributors to several key previous KR efforts**
  • RuleML and SWSL (Semantic Web Services Language) standards designs
  • SweetRules and Flora-2 systems

• **Especially:**
  • Michael Kifer, Mark Greaves, Dave Gunning, Mike Dean, Hui Wan, Paul Haley, Vinay Chaudhri, David Martin, Keith Goolsbey, Harold Boley, Said Tabet, and Guizhen Yang
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Thank You

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