A SILK Graphical UI for Defeasible Reasoning, with Biology Causal Process Example


Presentation at ISWC-2010****

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For More SILK Info:  [http://silk.semwebcentral.org](http://silk.semwebcentral.org)
SILK is part of Vulcan’s Project Halo:  [http://projecthalo.com](http://projecthalo.com)


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Outline and Summary

- **Background**: SILK overall, esp. its Hyper Logic Programs KR
  - A rule language and system with reasoner, UI, interchange
  - **Scalable higher-order defeasible** rules, plus many other advanced features
    - Omni-directionality: a novel expressive feature
    - Sound Interchange with FOL
    - External actions, events, and queries
  - Higher-abstraction KR closer to human cognition and social pragmatics
    - Tolerates and handles conflict. Represents debate, trust, and meta-knowledge.
    - Radically extends expressive power of RIF-BLD, SPARQL, RDF(S), OWL-RL
    - RIF-SILK dialect extends RIF-BLD
    - Remedies major limitations of semantic web’s current KR foundation

- **In the Demo itself**: a 1st SILK Graphical UI to query, edit, explain
- **Focus here is browsing justifications of defeasible conclusions**
  - **Novel** graphical approach for exploring prioritized defeat
  - Scenarios of rain, advertising policies, and biological causal process
    - These use omni-directionality
Supporting “Knowledge Debugging”

• **Type 1 Problem:** Some expected answer was **not** inferred
• **Type 2 Problem:** Some **unexpected** answer was indeed inferred

• **SILK’s defeasibility feature (desirable and powerful) raises new aspect:**
  • Type 1D Problem: Expected answers may have been unexpectedly **defeated**
  • Type 2D Problem: Unexpected answers may have been unexpectedly **not defeated**
  • **⇒ Critical:** Enable knowledge engineers (KEs) to explore justifications for Types 1D & 2D
  • E.g., to explore **plausible but failed** justifications for conclusions that do not appear

• **Justifications need to:**
  • Clearly show **argumentation** and its results
  • Support **interactive** exploration by the KE of the justification space
    • Hide most of the volume of justification graph, facilitate selective expansion and drill down
  • Clearly link operational-form lower-abstraction rules back to source-form higher-abstraction rules that have been **transformed** into operational-form
    • Link rules back to **source** files, to facilitate correction editing
Demo Screenshot
SILK research program (2008-) in Vulcan’s Project Halo

• For 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. E.g., textbooks/exams.
  • 1st yr college-level *Biology* is current domain focus: complex causal processes

• **Advanced KR language and system, for esp. defaults & processes**
  • Largest* rule research program in USA. Multi-institutional: primarily via contractors.
  • 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

• **Potential application areas in business and government**
  • Horizontal: policies, workflows; ontology mapping, knowledge integration
  • Vertical: e-commerce, defense intelligence, trust, biomed, financial, mobile

• [http://silk.semwebcentral.org](http://silk.semwebcentral.org)

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Ecology Ex. of Causal Process Reasoning

/* 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(0,Squamish,trout,400); /* 1st argument of fishCount is an integer time */
silk:opposes(fishCount(?s,?r,?f,?C1), 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,discharge,?r) and occupies(?f,?r);
/* Persistence (“frame”) axiom */
@pefc1 fishCount(?s+1,?r,?f,?p) :- fishCount(?s,?r,?f,?p);
/* Action effect axiom has higher priority than persistence axiom */
silk:overrides(tdf1,pefc1);
/* An action instance occurs */
@UhOh occurs(1,toxicDischarge,Squamish);

As desired: |= fishCount(1,Squamish,trout,400),
fishCount(2,Squamish,trout,0);

Notes: @… declares a rule tag. ? prefixes a variable. :- means if. != means ≠. opposes indicates
an exclusion constraint between two literals, which means “it’s a conflict if”.
SILK’s Goals

• 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.
SILK’s KR: **Hyper Logic Programs**

- New Extension of LP that is the first to **combine** key advanced features
- **Defaults** + **Higher-Order** + **External Actions/Events/Queries**
  - + Webized, Frames, Negation (neg and naf), Equality, Functions, Skolems, Aggregates, Integrity Constraints, Lloyd-Topor, …
- **Omni-directionality**: new feature, a focus in this demo/poster
  - Permit head disjunction, treat via directionalization. Handle multi-way conflicts.
  - Much broader FOL-sound interchange: *any* clause or universal formula, not just Horn
- Transforms knowledge from higher to lower abstraction levels
  - Raises expressive abstraction level. Higher is good for *knowledge acquisition* (KA)
  - Lower is good for reasoning (code reuse, optimization) and knowledge interchange
- **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”
- Uses new *argumentation theory* approach to defaults
  - ~20 “meta-” rules specify debate principles for defeat. Much easier to implement than code.
  - Enables much more expressiveness (e.g., HiLog). Much more efficient when updating.
- **RIF-SILK** dialect extends RIF-BLD (Basic Logic Dialect)
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

External Knowledge & Reasoners

KR Languages
- SILK, RIF-SILK
- RIF-BLD, OWL-RL
- SPARQL, RDF(S)
- SQL, Cyc, AURA

API (Java)

Language
- Interoperability
- Parsing & Serialization
- Abstract Syntax

Engine
- Querying
- Updating
- Actions

UI
- Advanced
  - Authoring
  - Explanation
- Basic
  - Instant Message
  - Command Line

Flora-2 Engine

XSB (InterProlog and ODBC interfaces)
Omni-directional Rules: Clausal case

- Hyper LP introduces the concept of an *omni-directional* (“omni”) rule. Basic case is **clausal**:
  - \( @G \ F \); where \( F \) has the syntactic form of a FOL clause
    - The prioritization tag \( (@G) \) is optional. Outer universal quantification is implicit.
    - E.g., \( @hi \) wet(lawn, nextMorning(?night)) or neg occur(rain, ?night);

- A clausal hyper rule is transformed, i.e., **directionalized**, from
  \( @G \ L_1 \) or \( L_2 \) or … or \( L_k \); where each \( L_i \) is an atom or the neg of an atom
  into a set of \( k \) **directed** rules, one for each choice of head literal:
  - \( @G \ L_1 : - \) neg \( L_2 \) and neg \( L_3 \) and … and neg \( L_k \);
  - \( @G \ L_2 : - \) neg \( L_1 \) and neg \( L_3 \) and … and neg \( L_k \);
  - …
  - \( @G \ L_k : - \) neg \( L_1 \) and neg \( L_2 \) and … and neg \( L_{k-1} \);

- **This is called the set of directional variant rules.**

- (NB: In a sophisticated Courteous variant, the directionalization transformation also outputs an *exclusion* statement that better handles multi-way conflicts.)

- **Still no reasoning by cases!!!** Cf. unit/linear resolution strategy in FOL.
Representational Uses for Defaults and Higher-Order

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
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]
Remedying FOL Semantics’ Lack of Scalability

- **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**
Interchange of Hyper LP $\leftrightarrow \rightarrow$ FOL

- Omnis are a natural source/target for interchange with FOL
- There is a (bi-)mapping $T$ that’s useful for such interchange. Its essence is:

<table>
<thead>
<tr>
<th>Hyper LP</th>
<th>FOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\langle G \ E \rangle$</td>
<td>$E$</td>
</tr>
<tr>
<td>$\langle G \ F :- B \rangle$</td>
<td>$F \leq B$</td>
</tr>
</tbody>
</table>

(E, F, and B are formulas. Certain restrictions apply: the formulas must be universal. The prioritization tag G is a term.)

- W.r.t. $T$: Hyper LP is sound and incomplete from FOL viewpoint
- When there is conflict, Hyper LP reasoning is usefully selective unlike FOL
- Usage 1: Import clausal/universal FOL into Hyper LP
  - Can give prioritization to the imported rules
    - E.g., based on source authority, recency, reliability
- Usage 2: Import Hyper LP conclusions into FOL
  - E.g., in conflict-free case. Hyper LP there lacks “reasoning by cases”
- Greatly generalizes well-known special case for definite Horn LP
  - Handles negation (neg) and attendant conflicts
  - Can cover “nearly full”* FOL, OWL, Common Logic, SBVR

* via skolemization