Highly Expressive yet Scalable Knowledge for Intelligence, Defense, and Security†

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slides also by Paul Haley* ** and Janine Bloomfield*

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‡ Semantic Technology for Intelligence, Defense, and Security http://stids.c4i.gmu.edu/
Outline

- Rulelog – more expressive logical KRR / advanced DB

- Textual Logic (TL): English $\leftrightarrow$ logic

- Case study with Demo: Federal Reserve Regulation W
  - Automate Decisions, with full Explanations

- Results from TL Authoring Experiment: Cell Membranes Bio
  - Rapid Collaborative Knowledge Acquisition (KA)

- Conclusions, and more about Applications incl. in IDS
Requirements on the logical KRR
for KA of Rich Logical K

• The logic must be expressively rich – higher order logic formulas
  • As target for the text interpretation

• The logic must handle exceptions and change, gracefully
  • Must be defeasible = K can have exceptions, i.e., be “defeated”, e.g., by higher-priority K
    • For empirical character of K
    • For evolution and combination of KB’s. I.e., for social scalability.
    • For causal processes, and “what-if’s” (hypotheticals, e.g., counterfactual)
    • I.e., to represent change in K and change in the world

• Infererencing in the logic must be computationally scalable
  • Incl. tractable = polynomial-time in worst-case
  • (as are SPARQL and SQL databases, for example)
Past Difficulties with Rich Logical K

• Hard to capture complex knowledge from English
  • ... and manage change of knowledge

• KRR not defeasible & tractable

• E.g.
  1. FOL-based – OWL, SBVR, CL: infer garbage
     • Perfectly brittle in face of conflict from errors, confusions, tacit context
  2. E.g., FOL and previous logic programs: run away
     • Recursion thru logical functions

• KRR not higher-order and meta enough
Knowledge often has **Exceptions**

- A.k.a. knowledge is *defeasible* (i.e., can be “defeated”)
- “A (eukaryotic) cell has a nucleus.”  … Except when it doesn’t 😊
  - A cell has no nucleus during anaphase. Red blood cells have no nuclei.
  - A cell has two nuclei between mitosis and cytokinesis. Some fungi are multinucleate.
- Exceptions / special cases are inevitably realized over time
  - E.g., knowledge is incomplete, multiple authors contribute, …
- Requiring entered knowledge to be strictly / universally true (exception-free) is impractical
  - Precludes stating generalities (the typical) and thus the population of authors
  - “The perfect is the enemy of the good”
- Exceptions manifest as contradictions, i.e., *conflict*
- Leveraging multiple sources of knowledge (e.g., KB merging) requires conflict resolution
Defeasibility is Indicated When…

- **Useful generalities** – **and** potential exceptions – coexist
  - Specify knowledge in detail/precision **appropriate** for various circumstances

- **Governing doctrine, definitions, or other knowledge, cannot be assured to be conflict-free, e.g.:**
  - Multiple sources of governing doctrine exist
    - Typically, no central authority resolves all conflict promptly
  - Truth depends on context
    - Yet context is rarely made fully explicit

- **Many broad realms are full of exceptions**
  - Policies, regulations, laws — and the workflows they drive
    - Multiple jurisdictions, organizations, contracts, origins
  - Learning and science. Updating. Debate.
    - May falsify previous hypotheses after observation or communication
  - Causal processes: changes to state, from interacting/multiple causes
  - Natural language (text interpretation): “there’s a gazillion special cases”
Classical Logic is a “Bubble”

• The semantic web demands logical reasoning

• Classical logic is the basis for most of today’s semantic web standards
  • W3C OWL & RDF(S), W3C RIF-BLD
  • OMG SBVR, ISO Common Logic

• In classical logic, unlike SILK, any contradiction makes everything garbage
  • Total brittleness
  • The odds of consistency drop almost exponentially with the # of axioms

Above right: http://img.dailymail.co.uk/i/pix/2007/11_03/BubblePA_468x585.jpg
Above:
http://www.dailymail.co.uk/sciencetech/article-1199149/Super-slow-motion-pictures-soap-bubble-bursting-stunning-detail.html
Rulelog: Overview

• First KRR to meet central challenge:
  \textbf{defeasible} + \textbf{tractable} + \textbf{rich}

• New rich logic: based on databases, not classical logic
  • Expressively extends normal declarative logic programs (LP)
  • Transforms into LP
  • LP is the logic of databases (SQL, SPARQL) and pure Prolog
    • Business rules (BR) – production-rules -ish – has expressive power similar to databases
  • LP (not FOL) is “the 99%” of practical structured info management today

• Advanced DB with new reasoning techniques to implement it

• Prototyped in Vulcan’s SILK

• Commercially supported in Coherent 1.0
  • Engine and HCI running on top of XSB Prolog

• Rulelog in draft as industry standard (RuleML submission to W3C RIF)
Textual Logic Approach: Overview

- **Logic-based** text interpretation & generation, for KA & QA
  - Map text to logic (“text interpretation”): for K and Q’s
  - Map logic to text (“text generation”): for viewing K, esp. for justifications of answers (A’s)
  - Map based on logic

- **Textual terminology** – phrasal style of K
  - Use words/word-senses directly as logical constants
  - Natural composition: textual phrase \(\leftrightarrow\) logical term

- **Interactive logical disambiguation technique**
  - Treats: parse, quantifier type/scope, co-reference, word sense
  - Leverages lexical ontology – large-vocabulary, broad-coverage
  - Initial restriction to stand-alone sentences – “straightforward” text
    - Minimize ellipsis, rhetoric, metaphor, etc.
  - Implemented in Automata Linguist™

- **Leverage defeasibility of the logic**
  - For rich logical K: handle exceptions and change
    - Incl. for NLP itself: “The thing about NL is that there’s a gazillion special cases” [Peter Clark]

KA = Knowledge Acquisition. QA = Question/Query Answering. NLP = Natural Language Processing.
Rulelog: more details

- Defeasibility based on *argumentation theories (AT)* [Wan, Grosof, Kifer 2009]
  - Meta-rules (~10’s) specify principles of debate, thus when rules have exceptions
  - Prioritized conflict handling. Ensures consistent conclusions. Efficient, flexible, sophisticated defeasibility.

- **Restraint**: semantically clean *bounded rationality* [Grosof & Swift, AAAI-13]
  - Leverages “undefined” truth value to represent “not bothering”
  - Extends well-foundedness in LP

- **Omniformity**: higher-order logic formula syntax, incl. hilog, rule id’s
  - Omni-directional disjunction. Skolemized existentials. [Grosof (invited), RuleML-2013]
  - Avoids general reasoning-by-cases (cf. unit resolution).

- Sound interchange of K with all major standards for sem web K
  - Both FOL & LP, e.g.: RDF(S), OWL-DL, SPARQL, CL

- Reasoning techniques based on extending tabling in LP inferencing
  - Truth maintenance, justifications incl. why-not, trace analysis for KA debug, term abstraction, delay subgoals [Andersen et al, RuleML-2013 (Challenge)]

For more info, see [Grosof, AAAI-13 Tutorial] – largely about Rulelog. Also see [Ontolog Forum 6/20/13, 10/31/13]
Rulelog *puts the Meta in* Knowledge

Rulelog has several expressive features for *meta* knowledge

- **Overall:** mix meta knowledge with “base” knowledge, in fine grain
  - Just as the web/markup mixes meta in *data* with “base” data, in fine grain

- **Hilog:** any atom can be treated as a term. Used also in Common Logic.
  - Provides higher-order syntax (bit restricted)
  - Semantics reduces (transforms) to first-order, and uses logical functions.

- **Reification:** any formula can be treated as a term. A.k.a. *quoting*.
  - Enables meta-statements about formulas. Provides modal syntax.

- **Rule id’s:** enables meta-statements about assertions (i.e., about rules)
  - Every assertion has a rule id, that is a constant in the logical language
  - Useful for provenance, defeasibility, restraint, and other purposes

- **Defeasibility:** any rule can have exceptions (non-monotonically)
  - Argumentation-theory approach: specify via rules the principles of defeat

- **Restraint:** bounded rationality, using the “undefined” (u) truth value
  - u represents “not bothering”
  - Specify via rules the principles of such “not bothering”
  - Radial restraint: treat as u every atom/literal whose size exceeds a fixed radius
Declarative Logic Programs (LP) is the Core KR today

• 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
  • Business Rules – the commercially dominant kinds (see next slide)
  • Semantic Rules
    • RuleML standards design, incl. SWRL. The main basis for RIF.
    • W3C Rule Interchange Format (RIF): -BLD, -Core. E.g., Jena tool.
  • Extension: Rulelog. E.g., Coherent’s tool.
  • Semantic Ontologies
    • W3C RDF(S)
    • W3C OWL-RL (= the Rules subset). E.g., Oracle’s tool for OWL.
  • Overall: LP is “the 99%”, classical logic is “the 1%”

• Relational DB’s were the first successful semantic technology
  • LP is the KR/logic that was invented to formalize them
• The Semantic Web today is mainly based on LP KR ... and thus essentially equivalent to semantic rules
  • You might not have realized that!
Commercially Dominant Legacy Kinds of Business Rules

• E.g., in OO applications, workflows

• Production rules (OPS5 heritage): e.g.,
  • IBM ILOG, Fair Isaac, Drools, Oracle, Jess: rule-based Java/C++ objects.

• Event-Condition-Action (ECA) rules (loose family), cf.:
  • business process automation / workflow tools.
  • active databases; publish-subscribe.

• Prolog. “logic programs”: as a full programming language
  • “Logic programming” is different from “declarative logic programs”

• LP is the core KR for production rules, ECA rules, and Prolog
  • … insofar as they are semantic (i.e., “declarative”)
  • But they are each only partially semantic
Example: Ontology Translation, leveraging hilog and exceptions

/* Company BB reports operating earnings using R&D operating cost which includes price of a small company acquired for its intellectual property. Organization GG wants to view operating cost more conventionally which excludes that acquisition amount. We use rules to specify the contextual ontological mapping. */

@{normallyBringOver}  ?categ(GG)(?item) :- ?categ(BB)(?item).
@{acquisitionsAreNotOperating}  neg ?categ(GG)(?item) :-
    acquisition(GG)(?item) and (?categ(GG) :: operating(GG)).
overrides(acquisitionsAreNotOperating, normallyBringOver). /* exceptional */
acquisition(GG)(?item) :- price_of_acquired_R_and_D_companies(BB)(?item).
R_and_D_salaries(BB)(p1001).  p1001[amount -> $25,000,000].
R_and_D_overhead(BB)(p1002).  p1002[amount -> $15,000,000].
price_of_acquired_R_and_D_companies(BB)(p1003).  p1003[amount -> $30,000,000].
R_and_D_operating_cost(BB)(p1003). /* BB counts the acquisition price item in this category */
R_and_D_operating_cost(GG) :: operating(GG).
Total(R_and_D_operating_cost)(BB)[amount -> $70,000,000]. /* rolled up by BB cf. BB’s definitions */
Total(R_and_D_operating_cost)(GG)[amount -> ?x] :- ...  /* roll up the items for GG cf. GG’s definitions */

As desired:  |=  R_and_D_salaries(GG)(p1001)
 |=  neg R_and_D_operating_cost(GG)(p1003) /* GG doesn’t count it */
 |=  Total(R_and_D_operating_cost)(GG)[amount -> $40,000,000]

Notation:  @{...} declares a rule tag.  ? prefixes a variable.  :- means if.  X :: Y means X is a subclass of Y.
\overrides(X,Y) means X is higher priority than Y.
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Financial Regulatory Compliance: Using Coherent software for Regulation W

Case Study from
Coherent Knowledge Systems, LLC
http://coherentknowledge.com
Banking Regulation

Problem:
- Complex set of regulations govern wide range of operations and activities that financial institutions engage in every day
- Compliance and Proof of compliance are essential
  - External: Outside regulators
  - Internal: Company’s management chain
- Automated support needed –
  - Current methods are expensive and unwieldy

Solution:
- Coherent Knowledge Systems – software and services
  - Automates decisions for compliance with banking regulation
  - Advanced database with automated logical reasoning
  - Explains fully how compliance decisions were reached
USA Federal Reserve Act:
Regulation W

• Concerns activities/transactions between a bank and “affiliates”
• Designed to limit risks
• Defines who is an “affiliate”, what is a “covered transaction”, whether a particular transaction is permitted

San Francisco’s Federal Reserve building
Interpreting Regulation W: 3 key aspects

1. Is the transaction’s counterparty an affiliate of the bank?

2. Is the transaction contemplated a covered transaction?

3. Is the amount of the transaction permitted?
Determining Whether Regulation W Applies

Two initial questions need to be answered in determining whether a transaction is subject to Regulation W. The first is whether the transaction is between a bank and an “affiliate” of the bank. The second is whether the transaction is a “covered transaction.”

Affiliate Definition. Regulation W applies to covered transactions between a bank and an affiliate of the bank.

The definition of an affiliate for purposes of Regulation W is set forth in section 223.2. The definition is broad, and includes:

- Any company that controls the bank;
- Any company that is controlled by a company that controls the bank;
- Any company that is controlled, directly or indirectly, by trust or otherwise, by or for the benefit of shareholders who beneficially or otherwise control, directly or indirectly, by trust or otherwise, the bank or any company that controls the bank;
- Any company in which a majority of its directors, trustees, or general partners (or individuals exercising similar functions) constitute a majority of the persons holding any such office with the bank or any company that controls the bank;
- Any company, including a real estate investment trust, that is sponsored and advised on a contractual basis by the bank or an affiliate of the bank;
- Any registered investment company for which the bank or any affiliate of the bank serves as an investment adviser;
- Any unregistered investment fund for which the bank or any affiliate of the bank serves as an investment adviser, if the bank and its affiliates own or control in the aggregate more than 5 percent of any class of voting securities or more than 5 percent of the equity capital of the fund;
Example Scenario:
A Loan to the Maui Sunset Hotel Group

Pacific Bank is considering a loan of $23 million dollars to the Maui Sunset hotel group to open a new location on the island.

Is this transaction allowed under Regulation W?

As part of that, one must ascertain if Maui Sunset could be considered an affiliate under Regulation W.

To watch the demo video, click here <TBD, on Coherent website>
Relationships and Other Data in the Demo Scenario

Americas Bank
Subsidiaries

Hawaii Bank

Alaska Bank

Kotzebue Bank

Pacific Bank

Capital Stock and Surplus

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Previous Loans

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Pertinent Regulation W Rules and Definitions

For this scenario, the following specific rules and definitions from the Federal Reserve Act were utilized:

Section 223.2 Definition of Affiliate:
- Any company, including a real estate investment trust, that is sponsored and advised on a contractual basis by the bank or an affiliate of the bank.
- A financial subsidiary of the bank

Section 223.3(h) Definition of Covered Transaction:
- An extension of credit to an affiliate

Quantitative Limitations:
- A bank may not engage in a new covered transaction with an affiliate if the aggregate amount of covered transactions between the bank and the affiliate would be in excess of 10 percent of the bank’s capital stock and surplus after consummation of the new transaction.
- Aggregate covered transactions between the bank and all affiliates are limited to 20 percent of the bank’s capital stock and surplus.
Regulation W Becomes Coherent Logic

Using Coherent tools:
- Regulation W is translated from English into logic, rapidly.
- A knowledge base is created, ready to make decisions and provide detailed explanations.

Sample English Text:
Any company that is advised on a contractual basis by the bank or an affiliate of the bank is considered an affiliate of the bank.

Logical representation:

```
affiliate(of)(?x1,?x2) :-
  (advised(by)(?x1,?x2)
   or
   (affiliate(of)(?x3,?x2) and advised(by)(?x1,?x3))).
```
Coherent software includes various tools. Two are:

- **Knowledge-base editor**
  Regulations, data, and linguistic information are entered here as logical formulations. Additional editing tools (not shown here) start directly from English.

- **Query window**
  Ask the knowledge base and get answers for decision making.
Sample Question:
“What proposed transactions are prohibited by Regulation W?”

Coherent software automatically makes a decision using the Regulation W knowledge base, including data facts from the example scenario:

The proposed transaction between Pacific Bank and Maui Sunset in the amount of $23.0 million is prohibited.
Explanation of How Decisions Are Reached

- Clicking on the ‘why’ button for a decision answer opens an explanation window.

- Clicking on any line in the explanation drills down to its supporting steps.
Why is the proposed transaction prohibited by Regulation W?

1. Is the transaction’s counterparty an “affiliate” of the bank? YES.

And here’s why ...

RegW prohibits the proposed transaction by Pacific Bank with Maui Sunset of $23.0 million
- The proposed transaction by Pacific Bank with Maui Sunset of $23.0 million is a RegW covered transaction
- Maui Sunset is a RegW affiliate of Pacific Bank
- Hawaii Bank is a RegW affiliate of Pacific Bank
  - There is common control of Hawaii Bank and Pacific Bank
    - Hawaii Bank is controlled by Americas Bank
    - Pacific Bank is controlled by Americas Bank
  - Pacific Bank is a subsidiary of Americas Bank
- Maui Sunset is advised by Hawaii Bank
- There is a proposed loan from Pacific Bank to Maui Sunset of $23.0 million
- There is a limit of $10.0 million for any proposed RegW covered transaction by Pacific Bank with Maui Sunset
- The proposed transaction of $23.0 million is greater than the RegW limit of $10.0 million
Why is the proposed transaction prohibited by Regulation W?

2. Is the transaction contemplated a "covered transaction"?

YES.

And here’s why ...
Why is the proposed transaction prohibited by Regulation W?

3. *Is the amount of the transaction permitted?*

NO. It went over the limit.
Why is the proposed transaction prohibited by Regulation W?

3. (continued) How was the limit calculated, using the bank’s capital, to determine whether the covered transaction was permitted?

Here’s how the aggregate-affiliates limit was determined:
Demo Summary: Coherent software ...

- Translates Regulation W into a Coherent Logic knowledge base, integrated with financial data

- Automates decisions for regulatory compliance

- Explains how conclusions were drawn
  - In readable English
  - The user can select the level of detail wanted
  - Supports human decision making, review, assurance, and proof of compliance
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Knowledge Acquisition for Deep QA: Expt.

- **Goal 1:** represent the knowledge in one chapter of a popular college-level science textbook, at 1st-year college level
  - Chapter 7 on cell membranes, in Biology 9th ed., by Campbell et al

- **Goal 2:** measure what KA productivity is achieved by KE’s
  - Assess level of effort, quality of resulting logic, and coverage of textbook

- **Software used in this case study:**
  - for translating English to logic
    - Automata Linguist™ and KnowBuddy™ (patents pending)
    - English Resource Grammar (http://www.delph-in.net/erg/)
  - for knowledge representation & reasoning
    - Vulcan, Inc.’s SILK (http://www.projecthalo.com/): prototype implementation of Rulelog
Summary of Effort & Results

• Captured 3,000+ sentences concerning cellular biology
  • hundreds of questions (2 examples herein)
  • 600 or so sentences directly from Campbell’s Biology textbook
  • 2,000 or so sentences of supporting or background knowledge

• Sentence length averaged 10 words up to 25 words
  • background knowledge tends to be shorter
  • disambiguation of parse typically requires a fraction of a minute
  • hundreds of parses common, > 30 per sentence on average
  • the correct parse is typically not the parse ranked best by statistical NLP

• Sentences disambiguated and formalized into logic in very few minutes on average
  • resulting logic is typically more sophisticated than skilled logicians typically produce

• Collaborative review and revision of English sentences, disambiguation, and formalization approximately doubled time per sentence over the knowledge base
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Tracked effort & collaboration per sentence
Sentences translated from English to logic
Knowledge Acquisition

- Note: the “parse” ranked first by machine learning techniques is **usually not** the correct interpretation
**BLOOMS TAXONOMY**

**KNOWLEDGE**
- Recall of information;
- Discovery; Observation;
- Listing; Locating; Naming

**COMPREHENSION**
- Understanding; Translating;
- Summarising; Demonstrating;
- Discussing

**APPLICATION**
- Using and applying knowledge;
- Using problem solving methods;
- Manipulating; Designing; Experimenting

**ANALYSIS**
- Identifying and analyzing patterns;
- Organisation of ideas;
- Recognizing trends

**SYNTHESIS**
- Using old concepts to create new ideas;
- Design and Invention; Composing; Imagining;
- Inferring; Modifying; Predicting; Combining

**EVALUATION**
- Assessing theories; Comparison of ideas;
- Evaluating outcomes; Solving; Judging;
- Recommending; Rating
A Bloom level 4 question

• If a Paramecium swims from a hypotonic environment to an isotonic environment, will its contractile vacuole become more active?

∀(\text{paramecium}(\text{x9}))
⇒∃(\text{hypotonic}(\text{environment})(\text{x13}))
∧∃(\text{isotonic}(\text{environment})(\text{x21}))
∧∀₁(\text{contractile(vacuole)}(\text{of}(\text{x9}))(\text{x31}))
⇒\text{if}(\text{then})(\text{become}(\text{x31},\text{more(active)}(\text{x31})),\text{swim}(\text{from}(\text{x13}))(\text{to}(\text{x21}))(\text{x9})))

• The above formula is translated into a hypothetical query, which answers “No”.
TL KA – Study Results

• Axiomatized ~2.5k English sentences during 2013:
  • One defeasible axiom in Rulelog (SILK syntax) per sentence
  • On average, each of these axioms correspond to > 5 “rules”
    • e.g., “rule” as in logic programs (e.g., Prolog) or business rules (e.g., PRR, RIF-PRD)

• << 10 minutes on average to author, disambiguate, formalize, review & revise a sentence

• The coverage of the textbook material was rated “A” or better for >95% of its sentences

• Collaboration resulted in an average of over 2 authors/editors/reviewers per sentence

• Non-authors rated the logic for >90% of sentences as “A” or better; >95% as “B+” or better

• TBD: How much will TL effort ↑ during QA testing?
• TBD: How much will TL effort ↓ as TL tooling & process mature?
TL KA – Study Results (II)

- **Expressive coverage: very good, due to Rulelog**
  - All sentences were representable but some (e.g., modals) are TBD wrt reasoning
  - This and productivity were why background K was mostly specified via TL
  - Small shortfalls (< few %) from implementation issues (e.g., numerics)

- **Terminological coverage: very good, due to TL approach**
  - Little hand-crafted logical ontology
  - Small shortfalls (< few %) from implementation issues
  - Added several hundred mostly domain-specific lexical entries to the ERG
TL KA: KE labor, roughly, per Page

• (In the study:)

• ~$3-4/word (actual word, not simply 5 characters)

• ~$500-1500/page (~175-350 words/page)

• Same ballpark as: labor to author the text itself

• … for many formal text documents
  • E.g., college science textbooks
  • E.g., some kinds of business documents
  • “Same ballpark” here means same order of magnitude

• TBD: How much will TL effort ↑ when K is debugged during QA testing?
• TBD: How much will TL effort ↓ as its tooling & process mature?
Outline

• Rulelog – more expressive logical KRR / advanced DB

• Textual Logic (TL): English $\longleftrightarrow$ logic

• Case study with Demo: Federal Reserve Regulation W
  • Automate Decisions, with full Explanations

• Results from TL Authoring Experiment: Cell Membranes Bio
  • Rapid Collaborative Knowledge Acquisition (KA)

• Conclusions, and more about Applications incl. in IDS
KA Advantages of Approach

• Approach = Rulelog + Textual Logic

• Rulelog as rich target logic
  • Can handle exceptions and change, and is tractable. Capably meta, generally.

• Textual terminology: logical ontology emerges naturally
  • From the text’s phrasings, rather than needing effort to specify it explicitly and become familiar with it
  • Perspective: Textual terminology is also a bridge to work in text mining and “textual entailment”

• Interactive disambiguation: relatively rapidly produces rich K
  • With logical and semantic precision
  • Starting from effectively unconstrained text

• Rulelog supports K interchange (translation and integration)
  • Both LP and FOL; all the major semantic tech/web standards (RDF(S), SPARQL, OWL, RIF, CL, SBVR); Prolog, SQL, and production/ECA rules. (Tho’ for many of these, with restrictions.)
Conclusions

• Leveraging recent research breakthroughs on:
  reasoning with rich knowledge in logic and text

• Making it practical
  • Implement highly expressive reasoning behavior
  • Meta knowledge
  • Explanations and provenance
  • Computational efficiency and scalability
  • Support English, incl. in authoring too
  • Social scalability of KA, incl. reuse. Standards support in path & interchange.

• Appears to be significant progress on the famous “KA bottleneck” of AI
  • “Better, faster, cheaper” logic. Usable on a variety of KRR platforms.

• It’s early days still, so lots remains to do
  • Tooling, e.g.: leverage inductive learning
  • More experiments, e.g., scale up
Application Areas overall

- Financial, Regulatory Compliance
- Intelligence Analysis, Defense, Security (IDS)
- Health Care, Clinical Guidance
- Education, Science
- E-Commerce
- Policies, Contracts, Legal
- Info Integration, Data Analytics
- Natural Language Processing, incl. HCI
App. Areas in Intel., Defense, Security

- Collaboration Support in Intelligence Analysis
  - Confidentiality. Debate. *In intel, knowledge and inferencing is itself the main asset and task.*

- Situation Awareness in Defense

- Integrate Processes in Operations

- Training and Testing

- Underlying:
  - Policies, regulations, commands, contracts, laws
  - Learning assistants: tell machine
  - Personalized learning: explanation-based tutoring and question-answering
  - Causal process models

- Deeper underlying:
  - Reasoning with defeasibility, explanations and provenance
  - Info integration, incl. ontology mapping
Many other app. realms intersect with Intel., Defense, Security

• Medical: battlefield, active duty and family, veterans
• E-Commerce: procurement
• Education: just-in-time training
• Financial
• Natural Language Processing, e.g., HCI in training
• Detecting non-compliance
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Thank You