Detailed Explanations in English of Rich Reasoning, for E-Learning and Compliance

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Coherent Knowledge Systems*

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Introduction

• Core Technology approach: Textual Rulelog implemented in Episto – Reasoning with Explanations

• Case Study 1: Automated Decision Support for Financial Regulatory and Policy Compliance

• Case Study 2: Episto for Education Technology – Digital Socrates, an interactive tutor

• Conclusions and Lessons Learned from the Case Studies
Coherent Knowledge: Company Overview

• Leverages over a decade of major government and privately funded research advances in artificial intelligence (AI) and semantic technologies. Founded 7/2013.

• Company offers: platform software product Episto™ + custom dev / services  
  • Current applications in compliance and e-learning. Other applications in plan.

• World-class founder team: created many industry-leading logic systems & standards  
  • XSB Prolog, RuleML, W3C RIF, W3C OWL-RL, IBM Common Rules, SWRL, SweetRules  
  • Extensive experience applying logic systems to numerous domains in govt. and biz.

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Creator, Flora.  
Co-Architect, W3C RIF.  
Prof., Stonybrook Univ.

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Episto™ – The Coherent Knowledge Platform

• Dramatically expands the capabilities of database and reasoning systems
  • Adding or updating assertions, and posing queries, is much easier, faster, cheaper, and more under user control
  • An advanced logic engine operates under the covers
  • Full explanations in English are provided, exposing the context and meaning behind the results
    • Every relevant assertion is a step in the chain of reasoning that leads to the final answer

• Benefits automation of:
  • Policies: organizational, compliance, and legal
  • Decision making: routine, exceptions, alerts
  • Learning: interactive tutor, in-depth explanation of solutions
  • Info Access: fine-grain control and tracking
  • Info Analysis: including collaboration and scenarios
  • Info Integration: from diverse sources, using structured info and text
Episto – Coherent Knowledge Management Platform

- Unprecedented flexibility in the kinds of complex info that can be stated as assertions, queries, and conclusions (highly expressive “knowledge” statements)
  - Almost anything you can say in English – concisely and directly
  - Just-in-time introduction of terminology
  - Statements about statements (meta knowledge)
  - State and view info at as fine a grain size as desired

- Unprecedented ease in updating knowledge
  - Map between terminologies as needed, including from multiple sources

- Conflict between statements is robustly handled (often arises during integration)
  - Resolved based on priority (e.g., relative authority), or else tolerated as an impasse

- Scalable and computationally well-behaved
Episto’s Reasoner & User Interface

• Textual Rulelog: Implementation of major research advances in logic (Rulelog) and how to map between logic and English (Textual Logic)
  • The most complete & highly optimized implementation available
  • Rulelog significantly extends Datalog, the logic of databases, biz rule systems (production/ECA/Prolog), semantic web ontologies, and earlier-generation semantic web rules cf. SWRL and RIF and RuleML
• Ergo component – Episto’s Reasoner with sophisticated algorithms
  • Reordering, caching, transformation, compilation, indexing, modularization
• Studio component – Episto’s User Interface with array of advanced techniques
  • Fast edit-test loop with award-winning toolset. Development environment.
  • Graph & other visualization of knowledge
• Knowledge interchange with leading and legacy systems
  • SQL, SPARQL, OWL. Others in dev or easy to add. Fully automatic.
• Open, standards-based approach. Builds on open source components.
  • Supports Rulelog draft industry standard from RuleML (submission to W3C & Oasis)
Coherent’s Episto™ Platform

 optionally: Custom Apps - E.g., dev’d by Coherent

Epistro

Studio

User Interface & Development Environment
Knowledge authoring
Explanation generation

Ergo
Reasoner Engine

Knowledge Base

queries, assertions, edits
answers, view updates, decisions, explanations

Users

External Services/Components

DBMS
Other SIMS
Apps

Complex Info
- English Text
- Learning Objects
- Policy Doc.’s

External Structured Info
- Data
- Views
- Rules
- Schemas & Ontologies

KB = Knowledge Base. WS = Web Services. SIMS = Structured Info Mgmt. Sys., e.g., sem tech for OWL or Horn rules.
Case Study 1: Automated Decision Support for Financial Regulatory/Policy Compliance

Problem: Current methods are expensive and unwieldy, often inaccurate

Solution Approach – using Textual Rulelog software technology:
• Encode regulations and related info as semantic rules and ontologies
• Fully, robustly automate run-time decisions and related querying
• Provide understandable full explanations in English
  • Proof: Electronic audit trail, with provenance
• Handles increasing complexity of real-world challenges
  • Data integration, system integration
  • Conflicting policies, special cases, exceptions
  • What-if scenarios to analyze impact of new regulations and policies

Business Benefits – compared to currently deployed methods:
• More Accurate
• More Cost Effective – less labor; subject matter experts in closer loop
• More Agile – faster to update
• More Overall Effectiveness: less exposure to risk of non-compliance
Demo of Episto for Compliance Automation:
US Federal Reserve Regulation W

- EDM Council Financial Industry Consortium
  Proof of Concept -
  - Enterprise Data Management Council (Trade Assn)
  - Coherent Knowledge Systems (USA, Technology)
  - SRI International (USA, Technology)
  - Wells Fargo (Financial Services)
  - Governance, Risk and Compliance Technology Centre (Ireland, Technology)

- Reg W regulates and limits $ amount of transactions that can occur between banks and their affiliates. Designed to limit risks to each bank and to financial system.

- Must answer 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?*

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**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.

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The Starting Point - Text of Regulation W
Query is asked in English

```

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>'Pacific Bank'</td>
<td>'Maui Sunset'</td>
<td>23.0</td>
</tr>
</tbody>
</table>
```

Why?
User Clicks the handles to expand the Explanations
Why is the proposed transaction prohibited by Regulation W?

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

   **YES.**

   - 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 a subsidiary of 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

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

2. Is the transaction contemplated a “covered transaction”? 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.
- 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?

3. Is the amount of the transaction permitted?

NO. It went over the limit.

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
- There is a limit of $10.0 million for any proposed RegW covered transaction by Pacific Bank with Maui Sunset
- There is an aggregated-affiliates limit of $10.0 million for any proposed RegW covered transaction by Pacific Bank with any affiliate
- There is an individual-affiliate limit of $250.0 million for any proposed RegW covered transaction by Pacific Bank with Maui Sunset
- The overall RegW limit of $10.0 million is the lesser of $10.0 million and $250.0 million
- 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?

3. (continued) Why is the aggregate-affiliates limit $10 million?
Examples of the Underlying Textual Rulelog

Executable Fact Assertions

• subsidiary(of)('Pacific Bank','Americas Bank').
• advised(by)('Maui Sunset','Hawaii Bank').
• bank('Hawaii Bank').
• company('Maui Sunset').
• capital(stock(and(surplus)))('Pacific Bank',2500.0).
• proposed(loan) (from('Pacific Bank'))(to('Maui Sunset')) (of(amount(23.0)))(having(id(1101))).
• previous(loan)(from('Pacific Bank'))(to('Hawaii Bank')) (of(amount(145.0)))(having(id(1001))).
• proposed(asset(purchase))(by('Pacific Bank')) (of(asset(common(stock)(of('Flixado')))))(from('Maui Sunset')) (of(amount(90.0)))(having(id(1202))).
/* A company is controlled by another company when the first company is a subsidiary of a subsidiary of the second company. */
@!{rule103b} /* declares rule id */
@@{defeasible} /* indicates the rule can have exceptions */
controlled(by)(?x1,?x2) :- /* if */
    subsidiary(of)(?x1,?x3) \and
    subsidiary(of)(?x3,?x2).

/* A case of an affiliate is: Any company that is advised on a contractual basis by the bank or an affiliate of the bank. */
@!{rule102b} @@{defeasible}
affiliate(of)(?x1,?x2) :-
( advised(by)(?x1,?x2)
  \or
(affiliate(of)(?x3,?x2) \and advised(by)(?x1,?x3))).
Executable Assertions: Exception Rule

@!{rule104e}
@{ready market exemption case for covered transaction'} /* tag for prioritizing */
\neg covered(transaction)(by(?x1))(with(?x2))
   (of(amount(?x3)))(having(id(?Id))) :-
   affiliate(of)(?x2,?x1) \and
   asset(purchase)(by(?x1))(of(asset(?x6)))(from(?x2))(of(amount(?x3)))
   (having(id(?Id))) \and
   asset(?x6)(has(ready(market))).

/* prioritization info, specified as one tag being higher than another */
\overrides('ready market exemption case for covered transaction',
   'general case of covered transaction').

/* If a company is listed on the New York Stock Exchange (NYSE), then the
   common stock of that company has a ready market. */
@!{rule201} @@{defeasible}
asset(common(stock)(of(?Company)))(has(ready(market))) :-
   exchange(listed(company))(?Company)(on('NYSE')).
Executable Assertions: Import of OWL

:- iriprefix fibof = /* declares an abbreviation */
 "http://www.omg.org/spec/FIBO/FIBO-Foundation/20120501/ontology/".

/* Imported OWL knowledge: from Financial Business Industry Ontology (FIBO) */
rdfs#subClassOf(fibob#BankingAffiliate, fibob#BodyCorporate).
rdfs#range(fibob#whollyOwnedAndControlledBy, fibob#FormalOrganization).
owl#disjointWith(edmc#Broad_Based_Index_Credit_Default_Swap_Contract, 
edmc#Narrow_Based_Index_Credit_Default_Swap_Contract).

/* Ontology Mappings between textual terminology and FIBO OWL vocabulary */
company(?co) :- fibob#BodyCorporate(?co).
fibob#whollyOwnedAndControlledBy(?sub,?parent) :- subsidiary(of)(?sub,?parent).

/* Semantics of OWL - specified as general Rulelog axioms */
?r(?y) :- rdfs#range(?p,?r), ?p(?x,?y).
?p(?x,?y) :- owl#subPropertyOf(?q,?p), ?q(?x,?y).
Case Study 2: Episto for Education Technology

*Digital Socrates, an interactive tutor*

Problem: Current automated tutors are expensive and time-consuming to encode, can’t re-use knowledge well, can’t teach critical thinking skills well

Solution Approach – using Textual Rulelog software technology:

- Encode educational materials such as textbooks, policy and legal documents, and company intelligence, as semantic rules and ontologies
- Create question/answer/explanation triples for study and test preparation
- Automatically generate *fine-grained* explanations – in English
  - Show each step in the logical chain of reasoning - go beyond the right answer to teach the student *Why* it is correct
  - Provide links to the source material on a per-sentence level
- Personalized and Adaptive Learning guidance based on what the student knows and what the student needs to learn

Business Benefits – compared to currently deployed methods:
- Critical Thinking Skills are addressed much better
- Cost effective and Scalable
- Knowledge is much more reusable
AP Physics Optics Problem

Question: “What is the Index of Refraction for a sample clear liquid given the Index of Refraction for air and the light beam angles in the two mediums?”

KEY CONCEPTS:
- Index of Refraction (IOR)
- Snell’s Law

FACTS:
- IOR of Air = 1.000277
- Beam Angle in Air = 0.52
- Beam Angle in LiquidX = 0.22

FORMULA for Snell’s Law:

\[
(IOR_{\text{Medium 2}}) \times \sin(\theta_2) = (IOR_{\text{Medium 1}}) \times \sin(\theta_1)
\]
The Index of Refraction for the unknown liquid is inferred using Snell’s Law

The Answer

Click on ‘Why’ for the Explanation
What is the Index of Refraction for a sample liquid? Show medium name and IOR \((\text{LiquidX}, 2.2775)\)?

The Index of Refraction for LiquidX is 2.2775 using Snell's Law.

- Snell's Law states that the Index of Refraction for Medium 1 = Index of Refraction for Medium 2 \(*\) \(\sin(\text{Beam Angle in Medium 2}) / \sin(\text{Beam Angle in Medium 1})\).
- The sample medium is LiquidX.
- The Index of Refraction for air is 1.00028.
- The beam angle in air is 0.52.
- The beam angle in LiquidX is 0.22.
- \(2.2775 = 1.00028 \times (\sin(0.52) / \sin(0.22))\).
- Air is not LiquidX.
Question: "The Sun is $1.5 \times 10^8$ km from Earth. How many more minutes would it take light from the Sun to reach Earth if the space between them were filled with an unknown liquid instead of a vacuum. Why?"

Query is asked in English

The answer is given in minutes.

Next, we can get the explanation by clicking on ‘Why?’

<table>
<thead>
<tr>
<th>liquid</th>
<th>difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>LiquidX</td>
<td>10.6458</td>
</tr>
<tr>
<td>LiquidZ</td>
<td>17.6638</td>
</tr>
</tbody>
</table>
How many more minutes would it take for light to travel from the Sun to the Earth if the space between them were filled with an unknown liquid instead of a vacuum? If LiquidX is an unknown liquid, it would take light 10.6458 more minutes to travel from the Sun to the Earth in LiquidX than in a vacuum.

- The length of time in minutes for light to travel from the Sun to the Earth in a vacuum is 8.33333
- The length of time in minutes for light to travel from the Sun to the Earth in a medium, LiquidX, is 18.9792
- The difference between 18.9792 and 8.33333 is 10.6458

How many more minutes would it take for light to travel from the Sun to the Earth if the space between them were filled with an unknown liquid instead of a vacuum? If LiquidX is an unknown liquid, it would take light 10.6458 more minutes to travel from the Sun to the Earth in LiquidX than in a vacuum.

- The distance from the Sun to the Earth is 1.5 x 10^8 km
- The speed of light in LiquidX is 131723.0 km/s
- 1138.75 km/s is 15000000 / 131723.0
- The difference in minutes, 18.9792, is 1138.75 seconds divided by 60 because there are 60 seconds in a minute
- The difference between 18.9792 and 8.33333 is 10.6458
The Answer and the Underlying Knowledge are all part of the Explanation in English

- Illustrates cumulative, modular character of the encoded knowledge. The reused knowledge needs no modification. This is key to scalability.
Lessons Learned from Case Studies

• Coherent’s Episto technology successfully automated Regulation W, demonstrating its utility for Regulatory and Policy Compliance
  • Highly Accurate on test data
  • Full Explanations – in English, with chain of reasoning and provenance
  • Reduces key elements of compliance risk
  • Cost Effective implementation – flexible; with electronic audit trail

• Textual Rulelog can be applied to Education via Digital Socrates tutor
  • Re-use of knowledge (complex concepts, facts, formulas)
  • Critical Thinking Skills addressed:
    • Answer plus Explanation including Concepts, Formulas, etc.
    • Content neutral platform

• Concrete Business Benefits for Financial Compliance and Education
  • More Cost Effective – less labor, subject matter experts in closer loop
  • More Agile – faster to update
  • More Overall Effectiveness – firmer deeper understanding
    • Lower risk of non-compliance or confusion
Thank You

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