Semantic Web Progress and Directions

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Semantic Web Perspectives

- **The Semantic Web means different things to different people. It is multi-dimensional**
  - **Distributed data access**
  - **Inference**
  - **Data Integration**
  - **Logic**
  - **Services**
  - **Search (based on term meaning)**
  - **Configuration**
  - **Agents**
  - **…**
- **Different users value these dimensions differently**
- **Theme: Machine-operational declarative specification of the meaning of terms**

Semantic Web Layers

Ontology Level

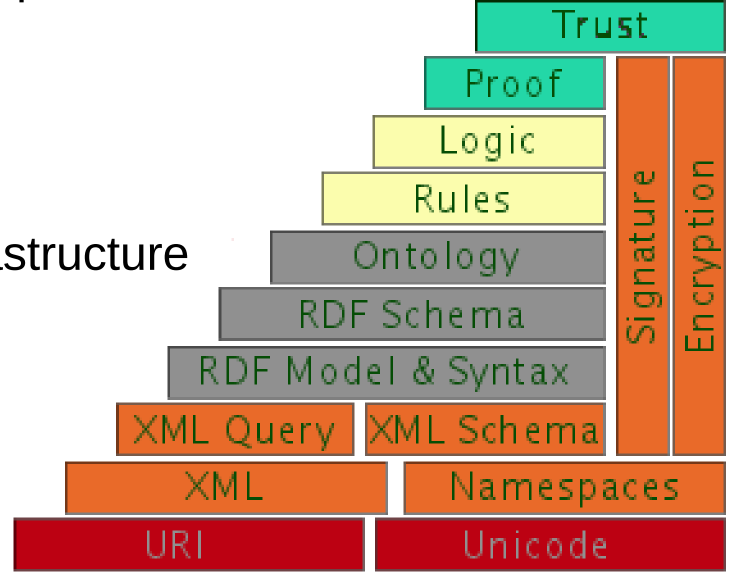
- Languages (CLASSIC, DAML-ONT, DAML+OIL, OWL, …)
- Environments (FindUR, Chimaera, OntoBuilder/Server, Sandpiper Tools, …)
- Services (OWL-S, SWSL, Wine Agent, Explainable SDS, …)
- Standards (NAPLPS, …, W3C's WebOnt, W3C's Semantic Web Best Practices, EU/US Joint Committee, OMG ODM, …

Rules : SWRL (previously CLASSIC Rules, explanation environment, extensibility issues, contracts, …)

Logic : Description Logics

Proof: PML, Inference Web Services and Infrastructure

Trust: IWTrust, TAMI, …



http://www.w3.org/2004/Talks/0412-RDF-functions/slide4-0.html

Semantic Web Progress from a W3C perspective

- **Semantic Web foundation specifications in recommendation status: RDF, RDF Schema, and OWL**
- **OWL Specs available from WebOnt working group page:**

  http://www.w3.org/2001/sw/WebOnt/

  Best starting points: OWL Overview and OWL Guide
- **Working Group Conclusion: RDF and OWL are Semantic Web standards that provide a framework for asset management, enterprise integration and the sharing and reuse of data on the Web.**
- **Press Release - http://www.w3.org/2004/01/sws-pressrelease**
- **Testimonials from a number of companies http://www.w3.org/2004/01/sws-testimonial**
- **WebOnt has completed as a working group**

W3C Standards view continued

- **Best Practices working group www.w3.org/2001/sw/BestPractices/**
- **Task forces on:**
  - **Applications and Demos http://esw.w3.org/topic/SemanticWebBestPracticesTaskForceOnApplicationsAndDemos - example – DOAP – “description of a project”**
  - **Multimedia Annotation http://www.w3.org/2001/sw/BestPractices/MM/**
  - **Ontology Engineering and Patterns - http://www.w3.org/2001/sw/BestPractices/OEP/**

    Example – representing classes as property values, semantic integration, n-ary relations, …
  - **Porting Thesauri - http://www.w3.org/2004/03/thes-tf/mission - SKOS - Simple Knowledge organization System**
  - **RDF/Topic Maps Interoperability - http://www.w3.org/2001/sw/BestPractices/RDFTM/**

W3C Best Practices, continued

- **Software Engineering - http://www.w3.org/2001/sw/BestPractices/SE/**

  Note on ODA and potential uses of the Semantic Web in Systems and SW engineering

- **Vocabulary Management - www.w3.org/2001/sw/BestPractices/VM/**

  E.g. best practice recipes for publishing RDF vocabularies

- **Wordnet - http://www.w3.org/2001/sw/BestPractices/WNET/tf**

Rules (SWRL to RIF)

- SWRL – Semantic web Rule Language combining OWL and RuleML
  - Submitted to W3C http://www.w3.org/Submission/2004/03/
- W3C Workshop on Rule Languages for Interoperability April 2005
  - http://www.w3.org/2004/12/rules-ws/
  - Identified 7 candidate technologies: WSML, RuleML, SWSL, N3, SWRL, Common Logic, TRIPLE
  - Identified driving use cases
- Rule interchange Working Group (RIF) formed chaired by IBM and ILOG
  - Dec 2005 Burlingame – kickoff
  - Feb 2006 France – use cases, design goals,
  - Should produce a rule language recommendation

Semantic Web Health Care and Life Sciences Interest Group

- **Community of Interest – designed to improve collaboration, research and development, and innovation adoption in the health care and life sciences industries…. Will bridge many forms of biological and medical information across institutions**
  - **http://www.w3.org/2001/sw/hcls/**
- **First F2F meeting – Jan 2006 - >60 attendees www.w3.org/2001/sw/hcls/f2f-2006/f2f-summary.html**
  - **6 task forces emerge**
  - **Other communities of practice under investigation… possibly the petroleum industry.. Norwegian Semantic Web days coming up.**

Semantic Web for Health and Life Sciences Task Forces

- **Structured Data to RDF** **http://esw.w3.org/topic/BioRDF_Charter**
- **Text to Structured Data** **www.ccs.neu.edu/home/futrelle/W3C-HCLSig/group-report-draft26Jan06.html**
- **Knowledge Life Cycle** **www.w3.org/2001/sw/hcls/task_forces/Knowledge_Ecosystem.html**
- **Ontologies working group** **esw.w3.org/topic/HCLS/OntologyTaskForce**
- **Adaptive Healthcare Protocols and Pathways** **esw.w3.org/topic/HclsigDscussionTopics/HclsSubGroupACPP**
- **ROI Analysis within HCLS**

Services

- **OWL-S came out of the DAML program as an ontology for web services - http://www.daml.org/services/owl-s/**
- **Version 1.2 “pre-release” available - http://www.daml.org/services/owl-s/1.2/**
- **Submitted to W3C as a member submission – Nov 2004 http://www.w3.org/Submission/OWL-S/**
- **Broadened to be more expressive and submitted to W3C**
  - **http://www.w3.org/Submission/2005/07/**
  - **SWSF – Semantic Web Services Framework**
  - **SWSL – Semantic Web Services Language**
  - **SWSO – Semantic Web Services Ontology**
  - **SWSF Application Scenarios**

Services, cont.

- Web Service Modeling Ontology submitted to W3C April 2005
  - http://www.w3.org/Submission/2005/06/
  - WSMO Web Service Modeling Ontology
  - WSML – Web Service Modeling Language
  - WSMX – Web Service Execution Environment (WSMX)
- WSDL-S Web Service Semantics submitted Nov 2005
- Semantic Web Services Interest Group formed: http://www.w3.org/2002/ws/swsig/
- June 2005 Meeting held in Innsbruck http://www.w3.org/2005/04/FSWS/program.html

Services Working Group

- **March 2006 – Semantic Annotations for Web Services Description Language Working Group launched www.w3.org/2002/ws/sawsdl/**
- **“The objective of the Semantic Annotations for WSDL Working Group is to develop a mechanism to enable annotation of Web services descriptions. This mechanism will take advantage of the WSDL 2.0 extension mechanisms to build a simple and generic support for semantics in Web services.”**

Other Semantic Web Stack Layers

- **Proof and Trust do not currently have interest or working groups**
- **Active work in progress…**
- **PML – Proof Markup Language is a proposed proof interlingua language http://www.ksl.stanford.edu/people/dlm/papers/pml-abstract.html**
- **Inference Web and related work provides tool sets for manipulating, browsing, summarizing, presenting, combining, checking, validating, searching, etc. PML**

Results of Recommendation Status and Tools

- **Tools options and depth are expanding**
  - **Browsers, editors, reasoners, etc**
  - **Open Source options (e.g., Protégé, SWOOP, PELLET, JTP, Chimaera, Inference Web, …)**
  - **Industrial supported options (e.g., Sandpiper, Cerebra, Top Quadrant, …)**
  - **Funded research programs expand for research (largely in Europe) and for application areas in US (e.g., CBio, PAL, NIMD, IKRIS, …)**

Example Semantic Web Usage – Cognitive Assistant that Learns and Organizes

- **DARPA IPTO funded program**
- **Personal office assistant, tasked with:**
  - **Noticing things in the cyber and physical environments**
  - **Aggregating what it notices, thinks, and does**
  - **Executing, adding/deleting, suspending/resuming tasks**
  - **Planning to achieve abstract objectives**
  - **Anticipating things it may be called upon to do or respond to**
  - **Interacting with the user**
  - **Adapting its behavior in response to past experience, user guidance**
- **Contributed to by 22 different organizations**

Working with a Cognitive Assistant

- **CALO users need to**
  - **Understand system behavior and responses**
  - **Trust system reasoning and actions**
- **To believe and act on recommendations from CALO, users need ways of exploring how and why the system acted, responded, recommended, and reasoned the way it did.**
- **Additional wrinkle: CALO knowledge, behavior, and assumptions are constantly changing through several forms of machine learning.**

A unified framework for explaining behavior and reasoning is essential for users to trust and adopt cognitive assistants.

Motivating Scenario: buying a laptop

1. **GetQuotes**
   - **Process requires 3 quotes from 3 different sources**
2. **GetApproval**
   - **Precondition: 3 valid quotes already obtained**
   - **Completion: approval form signed by an authorized approval representative**
3. **SendOrderToPurchasing**
   - **Precondition: signed approval form**
   - **Completion: order send to purchasing**

Getting an Explanation

Initial request and answer strategy

<user>: Why are you doing <subtask>?

<system>: I am trying to do <high-level-task> and <subtask> is one subgoal in the process.

Follow-up questions for mixed initiative dialogue

<user>: Why are you doing <high-level-task>?

<user>: Why haven't you completed <subtask> yet?

<user>: Why is <subtask> a subgoal of <high-level-task>?

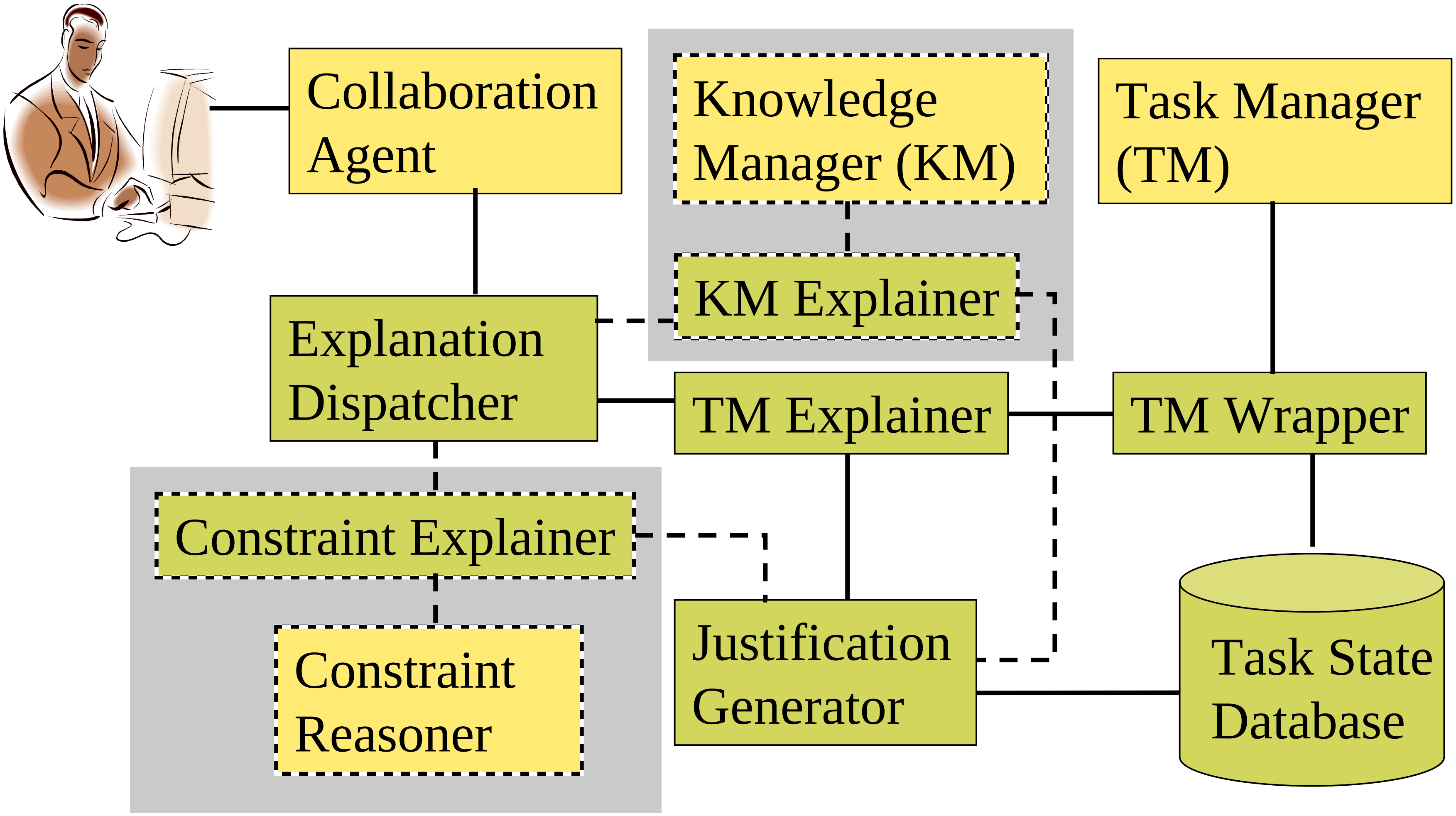
<user>: When will you finish <subtask>?

<user>: What sources did you use to do <subtask>?

The Integrated Cognitive Explanation Environment (ICEE): System Goals

- **Unified framework for explaining logical and task reasoning.**
- **Applicable to multiple task execution systems.**
- **Leverage existing InferenceWeb work for generating formal justifications.**
- **Underlying task reasoning useful beyond explanation.**
- **Provide sample implementation of end-to-end system.**

ICEE Architecture



Gathering Execution Information

Specification for introspective predicates

Three categories:

1. **Basic Procedure Information**
   Task provenance, including learned information
2. **Execution Information**
   Current and past task executions
3. **Projection Information**
   Future execution, and past alternatives

Sample Introspective Predicates: Provenance

- Author
- Modifications
  - Algorithm
  - Addition date/time
  - Data used
  - Collection time span for data
  - Author comment
  - Delta from previous version
  - Link to original

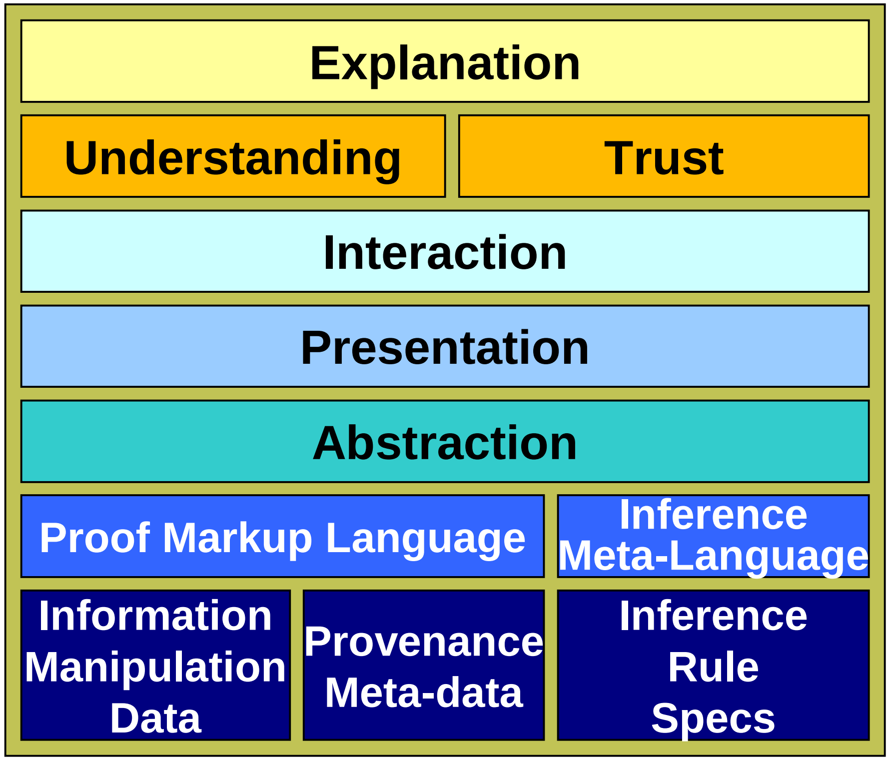
Glass, A., and McGuinness, D.L. 2006. Introspective Predicates for Explaining Task Execution in CALO. Technical Report, KSL-06-04, Knowledge Systems Lab., Stanford Univ.

Task Action Schema

- **Wrapper extracts portions of task intention structure through introspective predicates**
- **Store extracted information in action schema**
- **Designed to achieve three criteria:**
  1. **Relevance**
  2. **Reusability**
  3. **Generality**

An InferenceWeb Primer

1. Registry and service support for knowledge provenance.
2. Language for encoding hybrid, distributed proof fragments (both formal and informal).
3. Declarative inference rule representation for checking proofs.
4. Multiple strategies for proof abstraction, presentation, and interaction.



Framework for *explaining* reasoning and execution tasks by abstracting, storing, exchanging, combining, annotating, filtering, comparing, and rendering justifications from varied cognitive reasoners.

Representations in PML

- **Proof Markup Language (PML) is a proof interlingua**
- **Used to represent justification of information manipulation steps done by theorem provers, extractors, other reasoners**
- **Main components concern inference representation and provenance issues**
- **Specification written in OWL**

http://foo.com/Example.owl#Laptop

iw:NodeSet

iw:isConsequenceOf

iw:InferenceStep

iw:hasRule: ***SupportsTopLevelGoal***

iw:hasSourceUsage: ***TailorComment***

iw:hasEngine: ***SPARK***

iw:hasConclusion: ***(Supports GA BL)***

iw:hasLanguage: ***KIF***

Generating Formal Justifications

A justification for task *T* requires demonstrating:

1. **Relevance**

   Fulfilling *T* will further one of the agent's high-level goals

2. **Applicability**

   The conditions necessary to start *T* were met at the time *T* started

3. **Termination**

   One or more of the conditions necessary to terminate *T* have not been met

```
<iw:NodeSet rdf:about="file://spark1.owl#ns3">
  <iw:hasConclusion>(supports GetApproval BuyLaptop)</iw:hasConclusion>
  <iw:isConsequentOf rdf:parseType="Collection">
    <iw:InferenceStep iw:hasIndex="0">
      <iw:hasRule rdf:resource="http://ParentSupport.owl#ParentSupport"
           rdf:type="http://iw.stanford.edu/2004/07/iw.owl#DeclarativeRule"/>
      <iw:hasAntecedent rdf:parseType="Collection">
        <iw:NodeSet rdf:about="file://spark1.owl#ns2">
          <iw:hasConclusion> (parentOf BuyLaptop GetApproval) </iw:hasConclusion>
          <iw:isConsequentOf rdf:parseType="Collection">
            <iw:InferenceStep iw:hasIndex="0">
              <iw:hasRule rdf:resource="http://Told.owl#Told"/>
            </iw:InferenceStep>
          </iw:isConsequentOf>
        </iw:NodeSet>
        <iw:NodeSet rdf:about="file://spark1.owl#ns1">
          <iw:hasConclusion> (supports BuyLaptop BuyLaptop) </iw:hasConclusion>
          <iw:isConsequentOf rdf:parseType="Collection">
            <iw:InferenceStep iw:hasIndex="0">
              <iw:hasRule rdf:resource="http://SelfSupport.owl#SelfSupport"/>
            </iw:InferenceStep>
          </iw:isConsequentOf>
        </iw:NodeSet>
      </iw:hasAntecedent>
    </iw:InferenceStep>
  </iw:isConsequentOf>
</iw:NodeSet>
```

Producing Explanations

- **Dialogue starts with any of several supported questions types**
- **ICEE chooses a strategy: an approach for abstracting the formal justification, depending on:**
  - **User model**
  - **Context**
- **Justification is parsed to present portions relevant to query and strategy**
- **ICEE suggests follow-up queries to enable mixed initiative dialogue**

Explanation Example

Sample question type: task motivation

Why are you doing <subtask>?

Strategy: reveal task hierarchy

I am trying to do <high-level-task> and <subtask> is one subgoal in the process.

Alternate strategies:

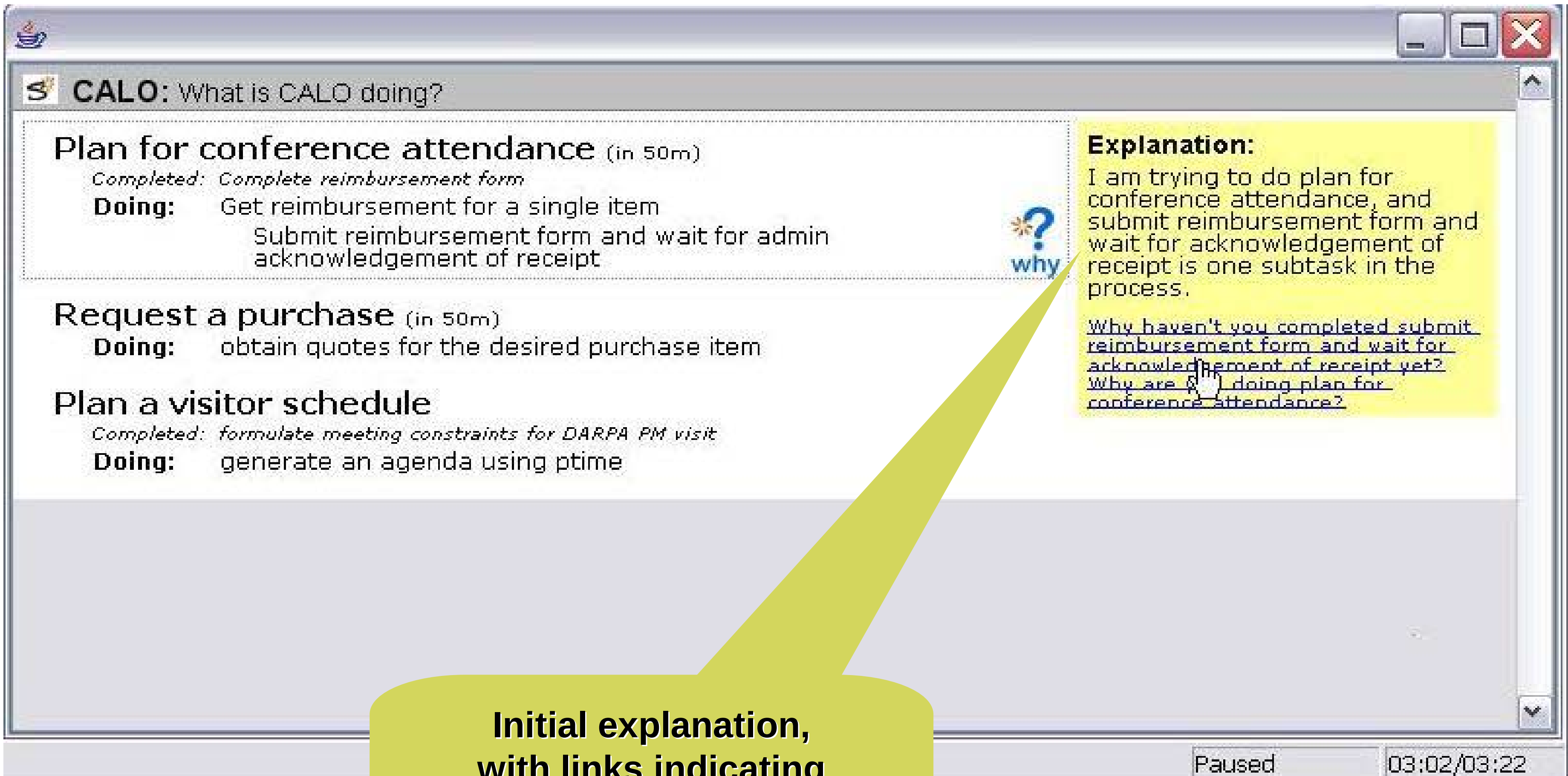
- **Provide task abstraction**
- **Expose preconditions**
- **Expose termination conditions**
- **Reveal meta-information about task dependencies**
- **Explain provenance related to task preconditions or other knowledge**

Follow-up questions

- **Request additional detail**
- **Request clarification of the given explanation**
- **Request an alternate strategy to the original query**

McGuinness, D.L.; Pinheiro da Silva, P.; Wolverton, M. 2005. Plan for Explaining Task Execution in CALO. Technical Report, KSL-05-011, Knowledge Systems Lab., Stanford Univ.

Sample Interface Linked to ICEE



**Initial explanation,
with links indicating
follow-up queries
and alternate strategies.**

Advantages to ICEE Approach

- Unified framework for explaining task execution and deductive reasoning exploiting semantic web technologies.
- Architecture for reuse among many task execution systems.
- Introspective predicates and software wrapper that extract explanation-relevant information from task reasoner.
- Reusable action schema for representing task reasoning.
- A version of InferenceWeb for generating formal justifications.

Discussion

- **Semantic Web infrastructure has reached recommendation status for the foundation**
- **Active working groups or interest groups on Rules and Services in addition to best practices**
- **Research in other areas of Semantic Web stack mature enough for usage**
- **Open source and commercial tools are emerging**
- **Growing number of example implemented use cases available**