CS 681 Fall 2008

Designing Expert Systems
10. Design Principles for Learning Assistants

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Learning Agents Center
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Agent Development Approaches
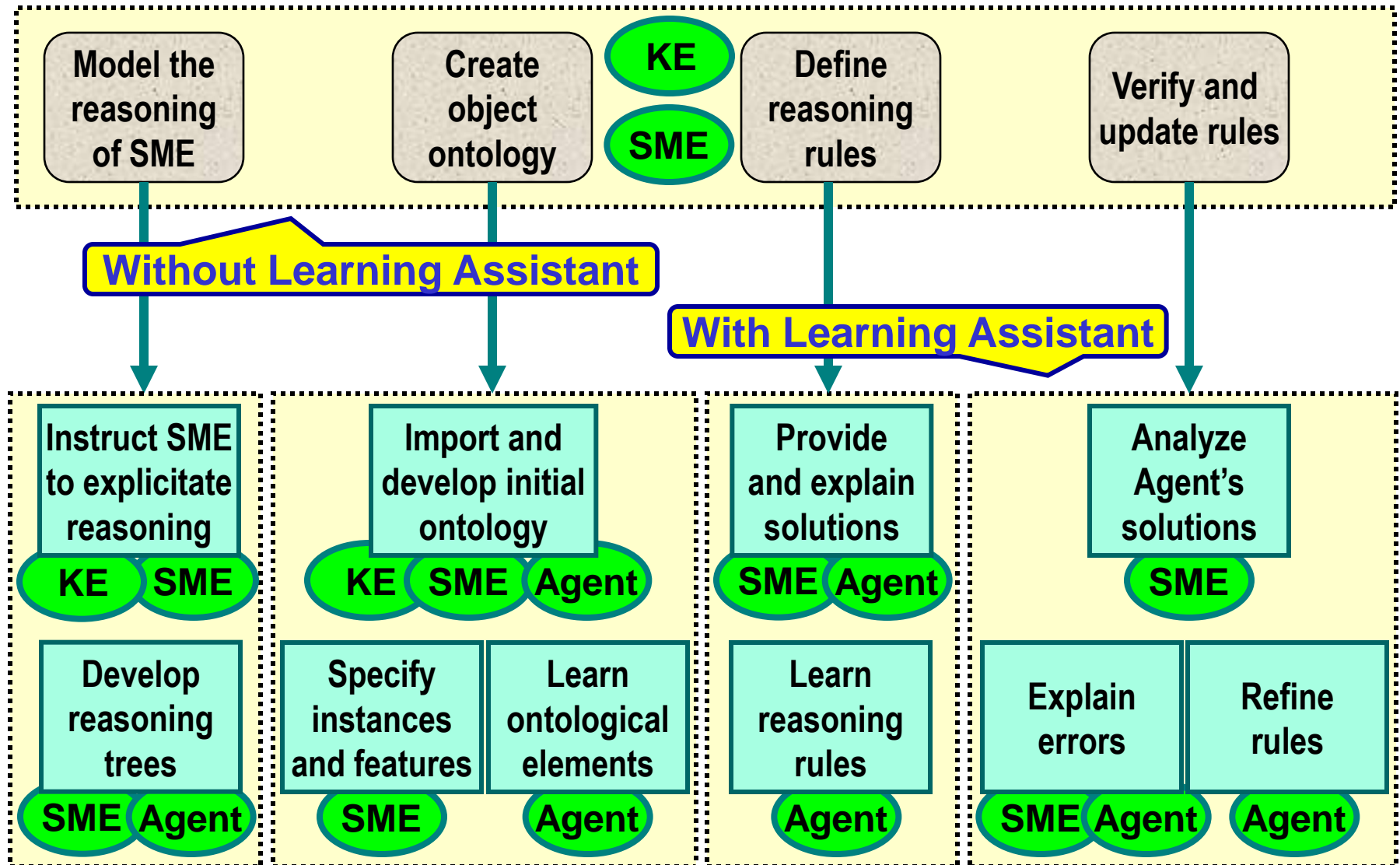
Overview: Design Principles

➡️ Spiral Development with SMEs and End-Users

Problem Solving Paradigm for User-Agent Collaboration

Multi-Agent and Multi-Domain Problem Solving

Knowledge Base Structuring for Knowledge Reuse

Integrated Teaching and Learning

Multistrategy Learning

Learning with an Evolving Representation Space

Mixed-Initiative Modeling, Learning and Problem Solving

Plausible Reasoning with Partially Learned Knowledge

User Tutoring in Problem Solving

Agent Architecture for Generality-Power Tradeoff

P1. Spiral Development with SMEs and End-Users

Intelligence analysis, Center of gravity determination, Course of action critiquing, Emergency response planning, Workaround reasoning, PhD advisor selection, Teaching higher order thinking skills.

Army War College

Air War College

George Mason University

Development of systematic approach to expert problem solving

Working closely with subject matter experts to model their reasoning

Modeling Expert's Reasoning

Education & Operations

Disciple

Learning Agents Research

Development and application of Disciple agents

Working closely with end users to receive crucial and timely feedback

DISCIPLE

Development of the Disciple theory for agent teaching by non-computer experts

Integration of many areas of Artificial Intelligence

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P2. Problem Solving Paradigm for User-Agent Collaboration

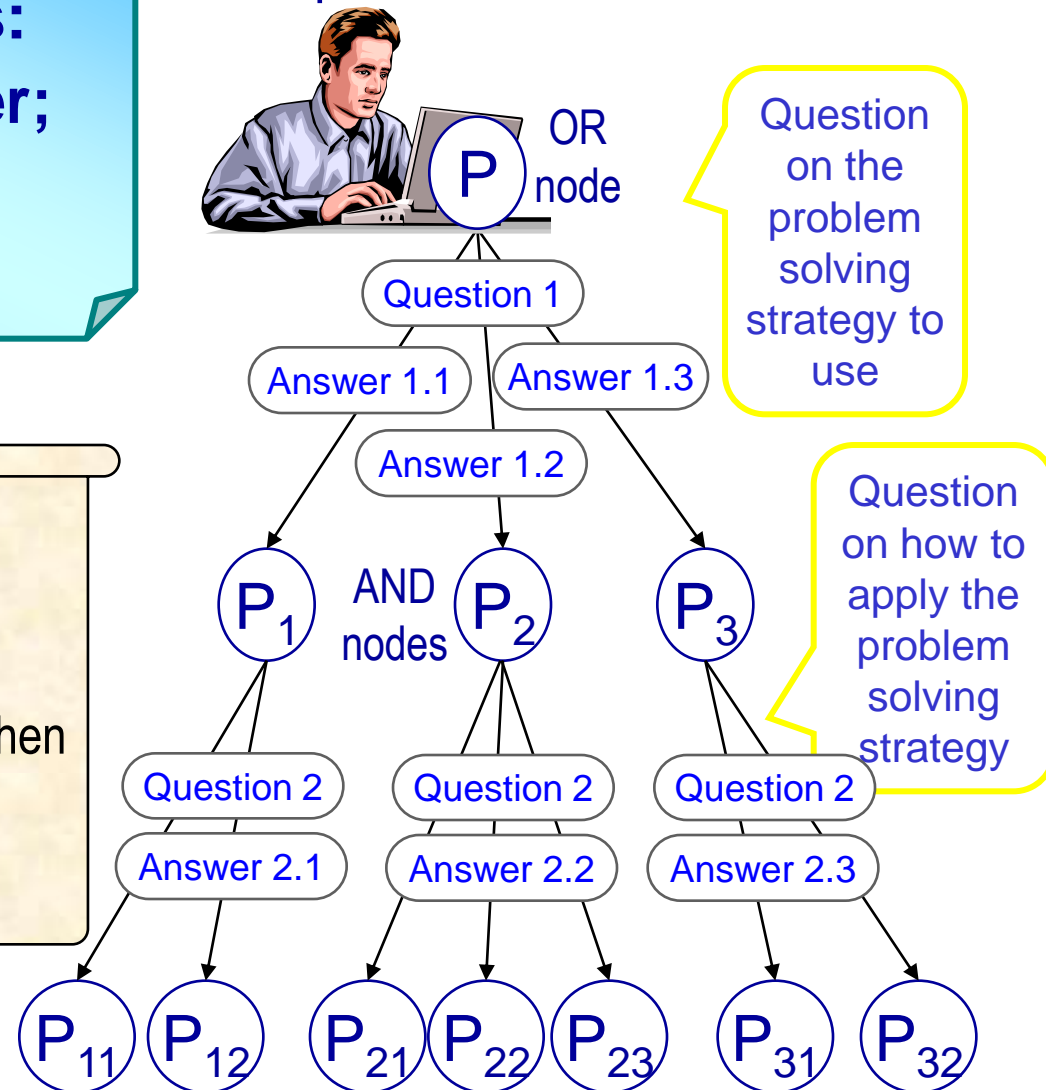**Develop a general problem solving paradigm which is:**
- **natural for a human user;**
- **appropriate for an automated agent.**

"I Keep Six Honest..."

I keep six honest serving-men
(They taught me all *I* knew);
Their names are What and Why and When
And How and Where and Who.

Rudyard Kipling

Problem Reduction Guided by Introspective Questions and Answers

P — OR node

Question 1

Answer 1.1 — Answer 1.3

Answer 1.2

Question on the problem solving strategy to use

P_1 — AND nodes P_2 — P_3

Question 2 — Question 2 — Question 2

Answer 2.1 — Answer 2.2 — Answer 2.3

Question on how to apply the problem solving strategy

P_{11} P_{12} P_{21} P_{22} P_{23} P_{31} P_{32}

Solution Synthesis

"One of the most highly developed skills in contemporary Western civilization is dissection; the split-up of problems into their smallest possible components. We are good at it. So good, we often forget to put the pieces back together again."

Alvin Toffler, Science and Change, Forward to Ilya Prigogine and Isabelle Stengers "Order Out of Chaos: Man's New Dialogue with Nature", Bantam Books, 1984.

Alvin Toffler

Problem-Reduction/Solution Synthesis Paradigm

The reduction representation of a class of problems is a quadruple (P, S, RO, OS) where:

P - class of problems;

S - solutions of problems;

RO - reduction operators, each reducing a problem to sub-problems and/or solutions,

SO - synthesis operators, each synthesizing the solution of a problem from the solutions of its sub-problems.

A problem P_1 is solved by:

- successively reducing it to simpler problems through the application of the reduction operators;

- finding the solutions of the simplest problems;

- successively combining these solutions through the application of synthesis operators until the solution of the initial problem is obtained.
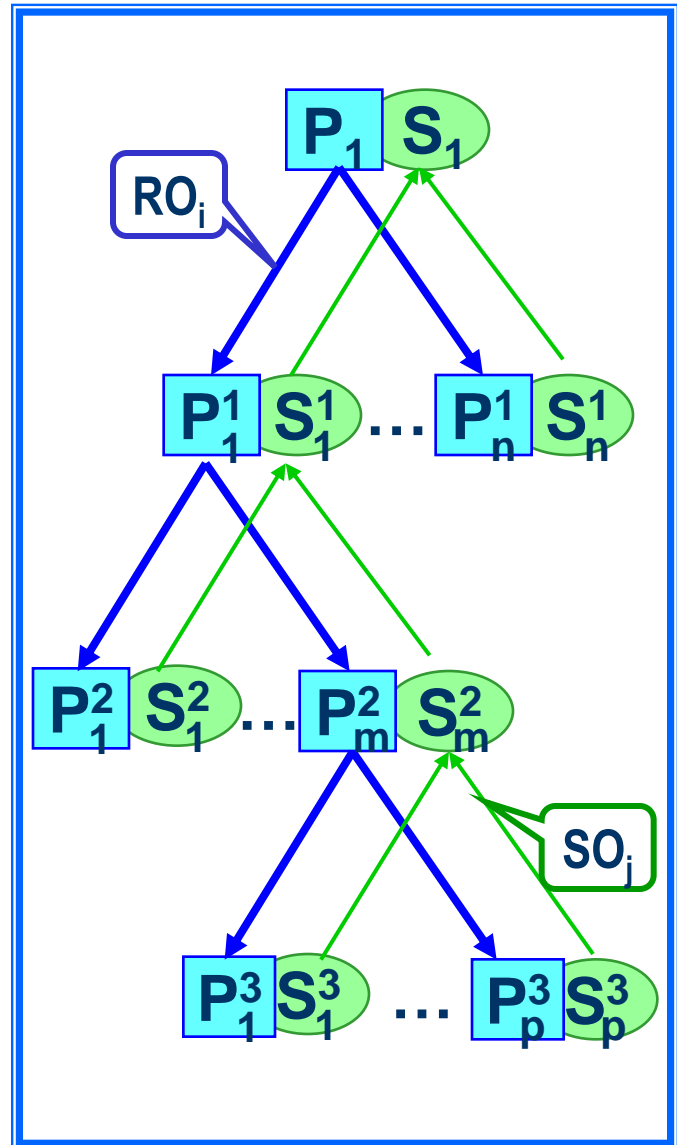
Sample Agent: Analyst's Cognitive Assistant

Analytic Assistance
Empowers the analysts through mixed-initiative reasoning for hypotheses analysis, collaboration with other analysts and experts, and sharing of information.

Learning
Rapid acquisition and maintenance of subject matter expertise in intelligence analysis which currently takes years to establish, is lost when experts separate from service, and is costly to replace.
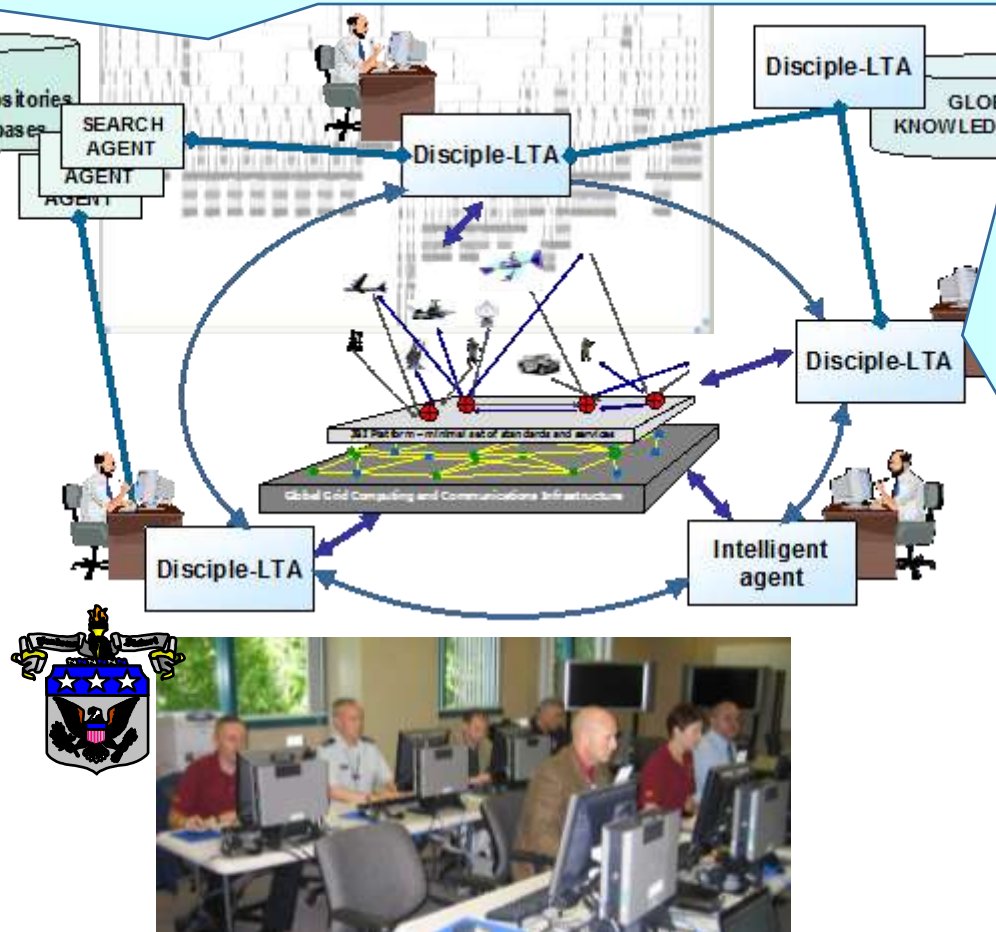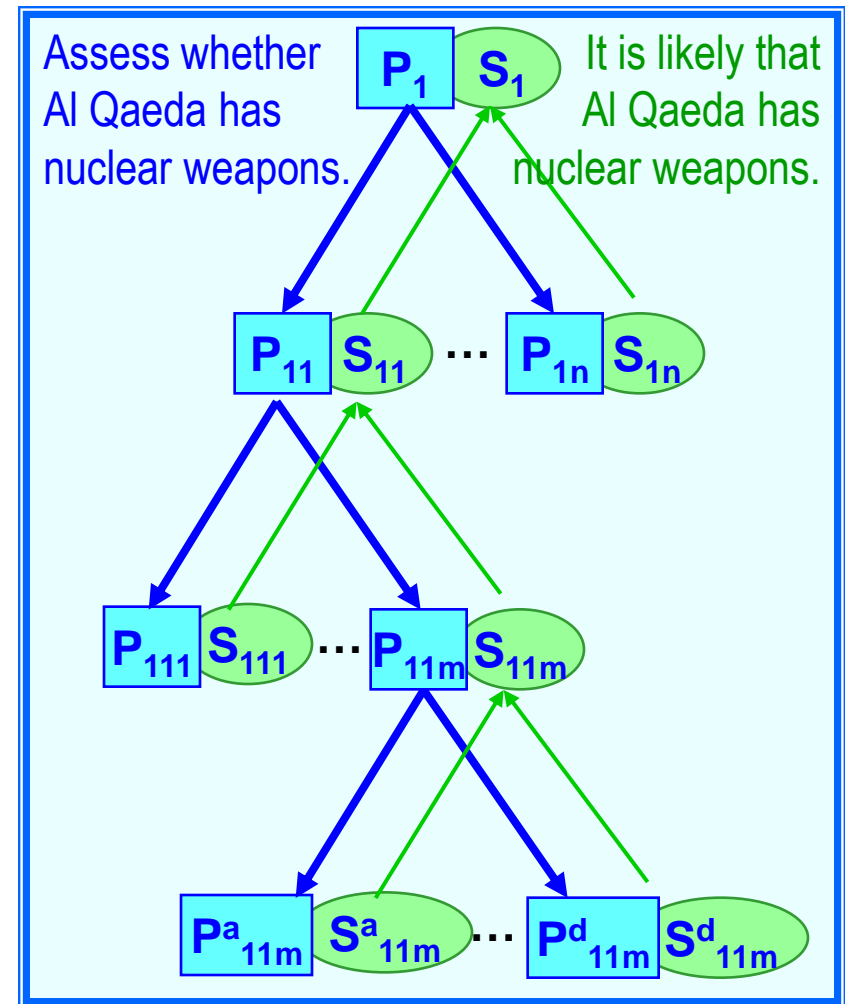
Tutoring
Helps new intelligence analysts learn the reasoning processes involved in making intelligence judgments and solving intelligence analysis problems.

Hypothesis Analysis through Problem Reduction

1) A complex hypothesis analysis problem is successively reduced to simpler problems that either have known solutions or can be solved through evidence analysis.

2) Potentially relevant pieces of evidence for the unsolved problems are identified.

3) The pieces of evidence are analyzed to obtain solutions for the unsolved problems.

4) The solutions of the simplest problems are successively combined to obtain the solution of the initial problem.

Assess whether Al Qaeda has nuclear weapons.

It is likely that Al Qaeda has nuclear weapons.

P_1 S_1

P_{11} S_{11} ... P_{1n} S_{1n}

P_{111} S_{111} ... P_{11m} S_{11m}

P^a_{11m} S^a_{11m} ... P^d_{11m} S^d_{11m}

Remote	Unlikely	Even chance	Probably, Likely	Almost certainly

National Intelligence Council's standard estimative language

Demo: Analytic Assistance
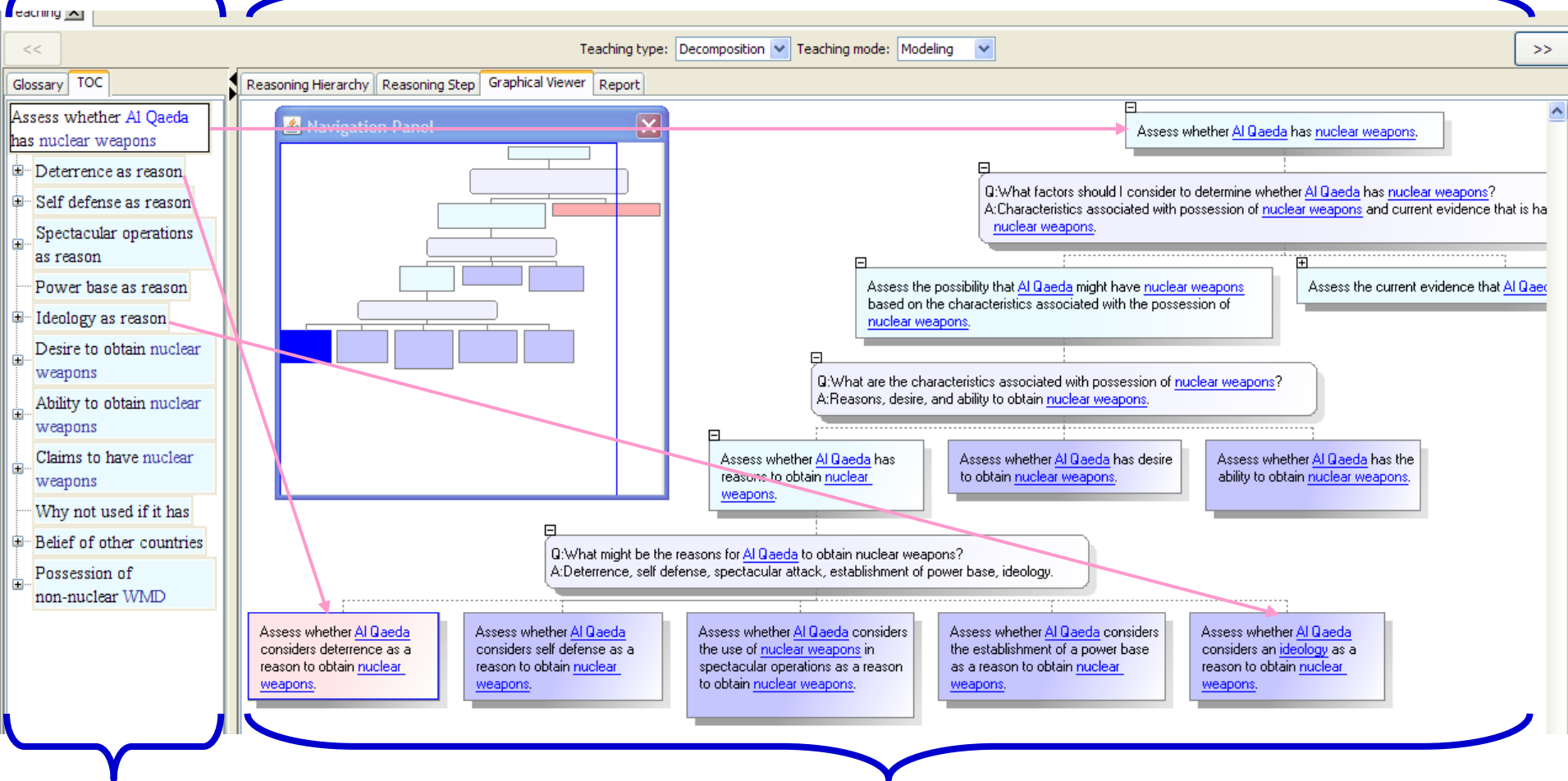
Disciple-LTA Demo: Analytic Assistance

collaborate

Disciple Agent **KB**

Problem Reduction: Abstract and Detailed Reasoning

Main problems

Reduction of a main problem to its main subproblems

Abstract tree

Detailed tree

Problem Reduction and Solution Synthesis

Solution Synthesis: Illustration

Analyzed problem

Synthesized solution

This is only an example — not to be taken as a current analytic estimate

Disciple-LTA makes very clear:
The analysis logic; What evidence was used and how;
What assumptions have been made; What is not known.
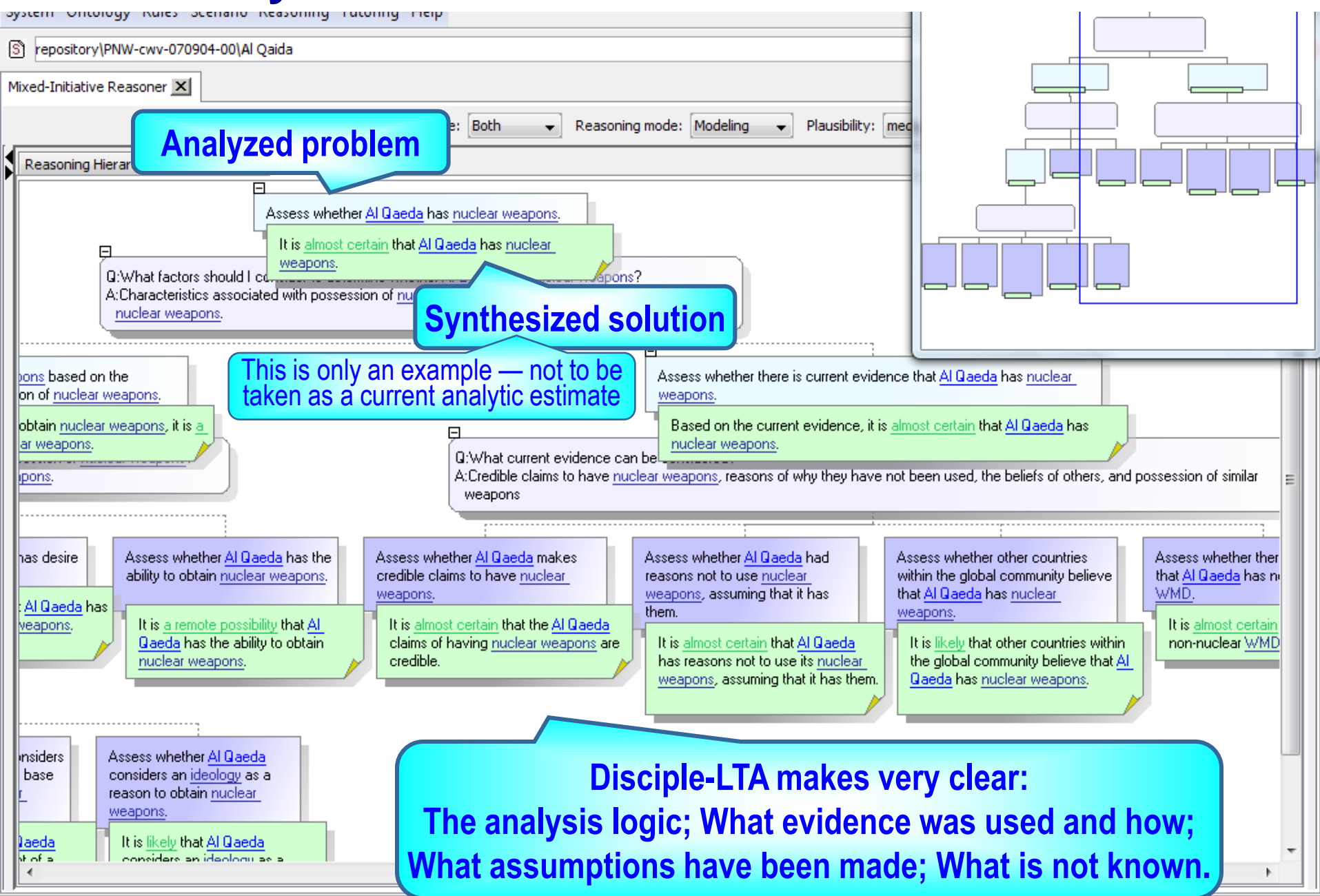
Assumptions-based Analysis

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P3. Multi-Agent and Multi-Domain Problem Solving

Develop a general problem solving paradigm that facilitates:
- **collaboration between users assisted by their agents;**
- **solving problems requiring multi-domain expertise.**
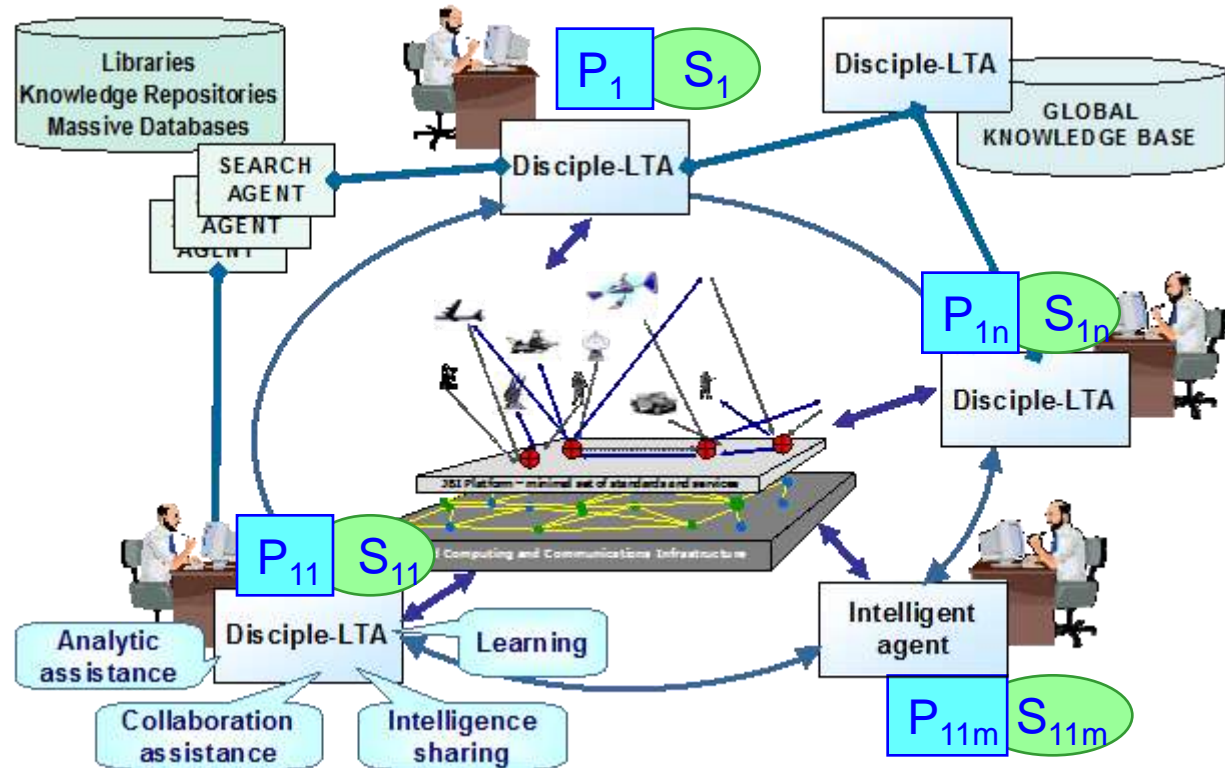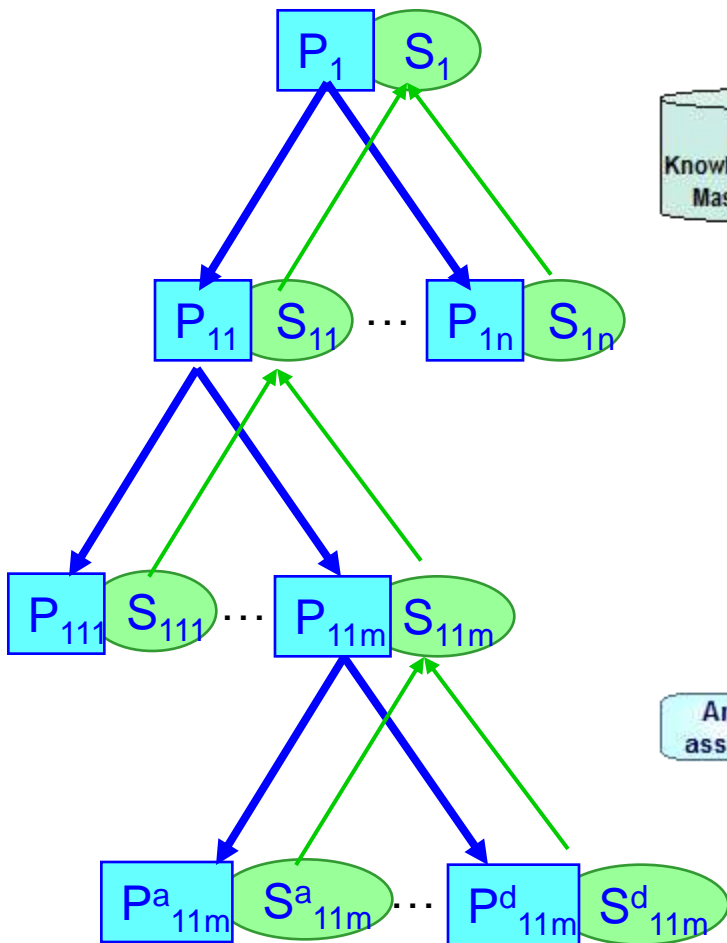
Service-Oriented Disciple Systems

Problem: *Assess whether Al Qaeda has nuclear weapons.*

Subproblem: *Assess whether other countries within the global community believe that Al Qaeda has nuclear weapons.*

Subproblem: *Assess whether Al Qaeda makes credible claims to have nuclear weapons.*

UDDI

Hypothesis Analysis Broker

Check UDDI for registered competence

Perform analysis

1

Ask broker for solutions

2

3

5

Receive solutions

6

Integrate Solutions

4

Solicit / receive solutions

Disciple-LTA Client

7

Upload reasoning tree in Catalyst

Subproblem: *Assess whether other countries within the global community believe that Al Qaeda has nuclear weapons.*
Solution: *It is likely that other countries within the global community believe that Al Qaeda has nuclear weapons.*

Disciple-LTA Clients

Disciple LTA Servers

Catalyst

Hypothesis Analysis Web Service

Subproblem: *Assess whether Al Qaeda makes credible claims to have nuclear weapons.*
Solution: *It is almost certain that the Al Qaeda claims of having nuclear weapons are credible.*

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P4. Knowledge Base Structuring for Knowledge Reuse

Structure the knowledge base into two parts:
o its more general and reusable components;
o its more specific components.

Disciple: Knowledge Base Structuring

- The object ontology which may be reused from existing knowledge repositories;

- The problem solving rules which are learned from the subject matter expert.

Knowledge Base

Object Ontology
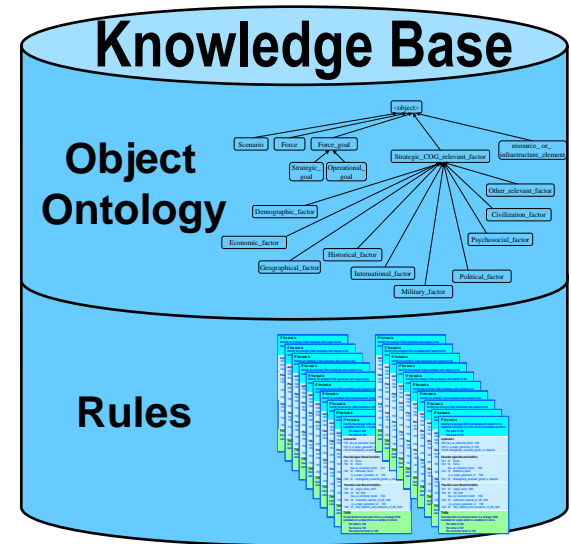
Rules

Knowledge Base = Object Ontology + Rules

The ontology is a hierarchical description of the domain objects.

authoritative record evidence

testimonial evidence

type-based evidence

testimonial evidence obtained at second hand

testimonial evidence as opinion based on analysis

testimonial evidence based upon direct observation

testimonial evidence about tangible evidence

chart evidence

videotape evidence

audiotape evidence

tangible evidence

object evidence

image evidence

measurement evidence

document evidence

Interpretation: Al Qaeda has chemical and nuclear weapons as deterrent.
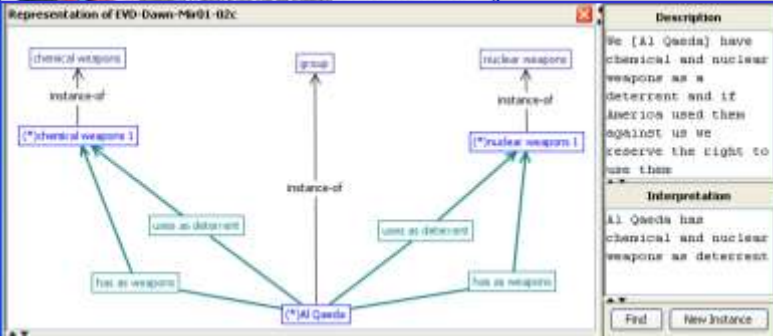
Knowledge Base = Ontology + Rules

Rules specify general problem reduction or solution synthesis steps

Analysis Tree

P_1 S_1

P_{11} S_{11} … P_{1n} S_{1n}

P_{111} S_{111} … P_{11m} S_{11m}
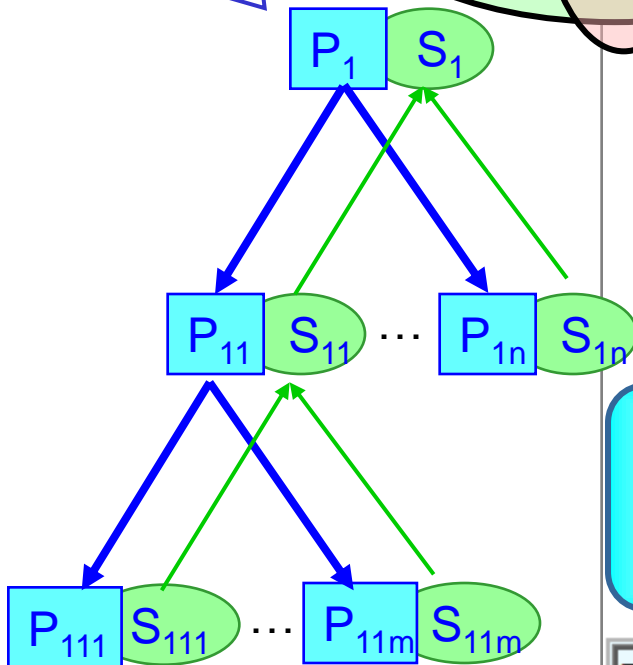
Partially learned rule

IF:	Assess whether there are states with nuclear weapons willing to sell nuclear weapons to ?O1.

Q:	Which is a nuclear state which is not an enemy of ?O1 and does not oppose the proliferation of nuclear weapons?
A:	?O2

MAIN CONDITION

Var	Lower Bound	Upper Bound
?O1	(terrorist group)	(actor)
?O2	(nuclear state)	(nuclear state)

EXCEPT WHEN CONDITION 1

Var	Lower Bound	Upper Bound
?O1	(terrorist group)	(actor)
?O2	(superpower, nuclear state)	(actor)

Var	Relationship	Var
?O2	perceives as enemy	?O1

EXCEPT WHEN CONDITION 2

Var	Lower Bound	Upper Bound
?SI1	[medium - medium]	[very low - very high]
?O2	(nuclear state)	(actor)

Var	Relationship	
?O2	degree of opposition to nuclear weapons proliferation	?SI1

THEN:	Assess whether ?O2 is willing to sell nuclear weapons to ?O1.

*To assess whether there are states that may be willing to sell nuclear weapons to an actor, **one has to consider each nuclear state** and assess whether that state may be willing to sell nuclear weapons to that actor, **except for** the case in which the nuclear state is an enemy of that actor and also **except for** the case when the nuclear state opposes the proliferation of nuclear weapons.*

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Control of Modeling, Learning and Problem Solving

Problem

Mixed-Initiative Problem Solving

Reasoning Tree

Extend Reasoning Tree

Reject Reasoning Steps

Accept Reasoning Step

Ontology + Rules

Learned Rules

Refined Rules

Refined Ontology

Explain Examples

Explain Examples

Explain Examples

Rules Refinement

Rules Learning
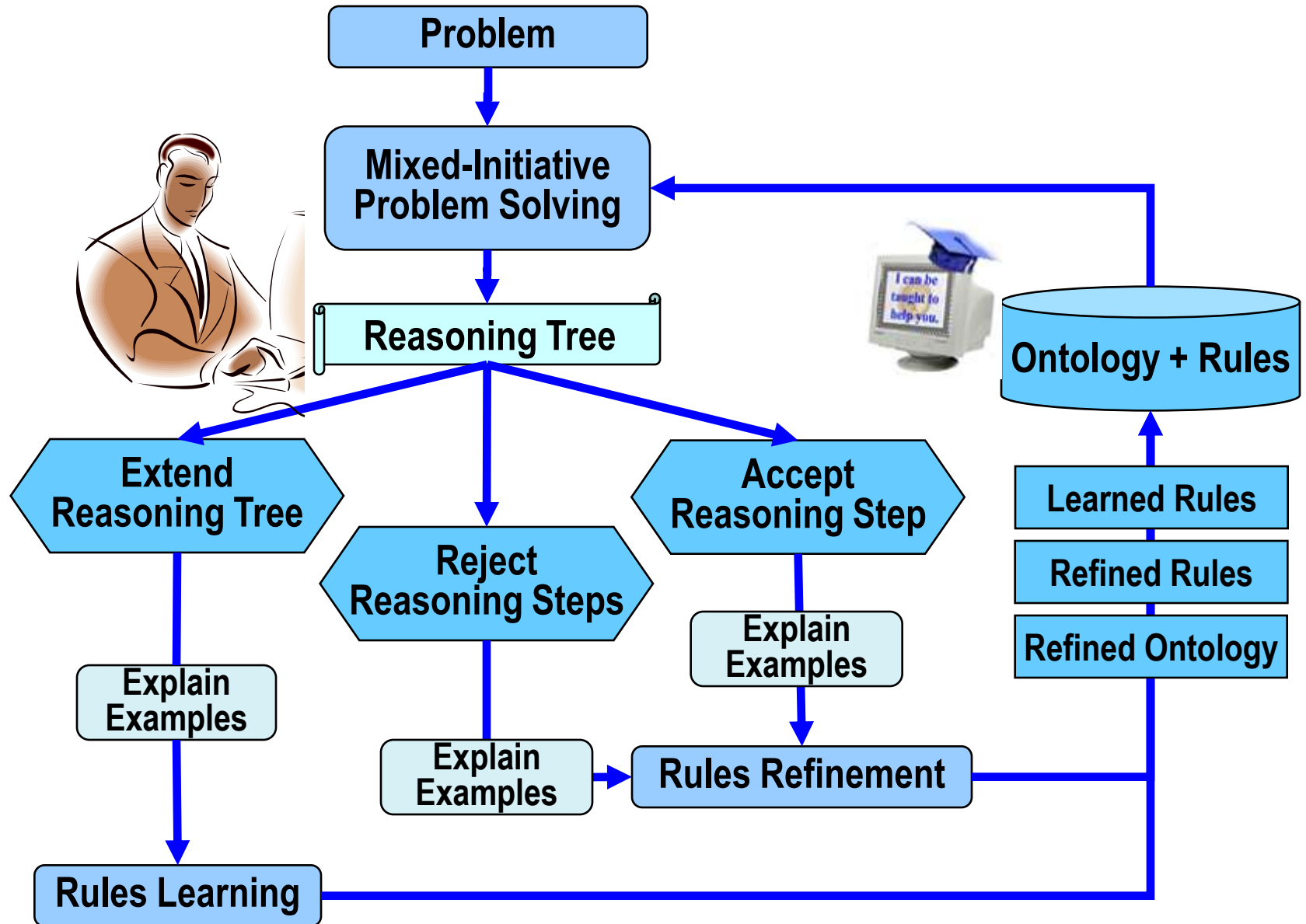
P5. Integrated Teaching and Learning

Develop agent teaching and learning methods where the subject matter expert helps the agent to learn (e.g. by giving examples, hints and explanations), **and the agent helps the expert to teach it** (e.g. by asking relevant questions).

examples, facts, rules

learning hints

Input knowledge

Explicit learning guidance

Problem solving behavior

Explicit teaching guidance

classification of examples, solutions to problems

questions
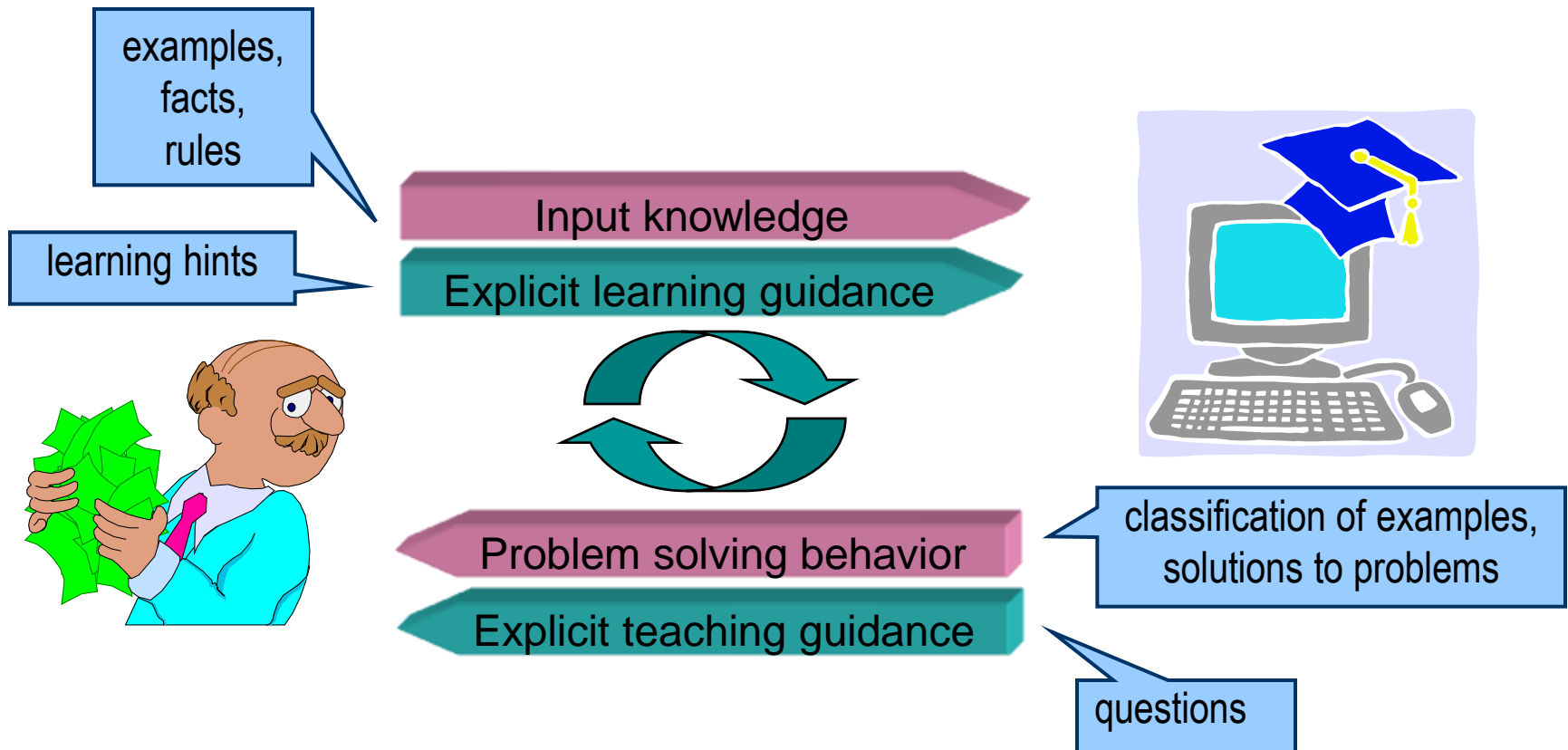
Integrated Teaching and Learning in Disciple

Analogy and Hint Guided Explanation

guidance, hints

plausible explanations

Example of problem reduction step

analogy   NLP

Knowledge Base

Analogy-based Generalization

Rule with Plausible Version Space Condition

Upper Bound

LowerBound

Incomplete explanation
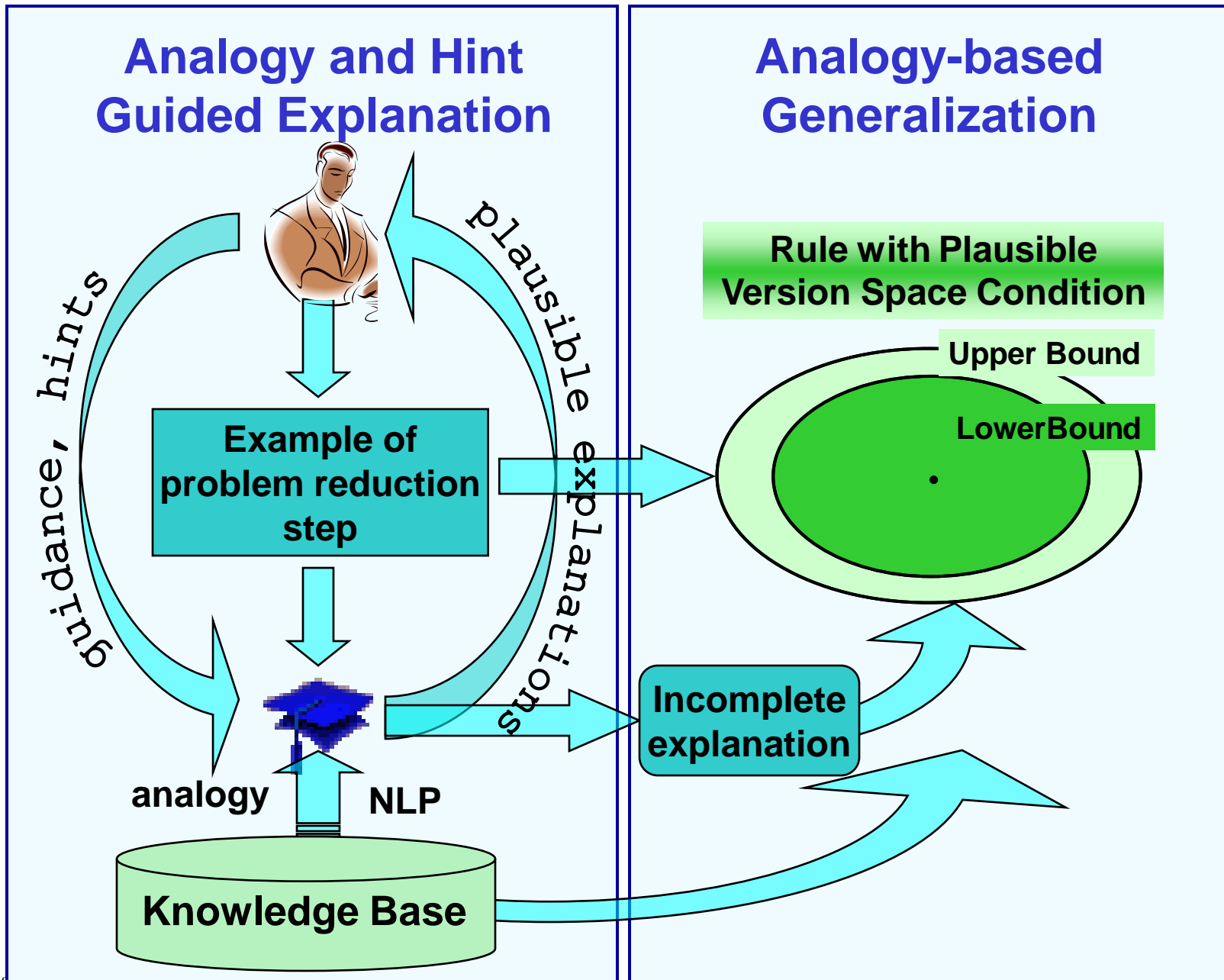
Reasoning Rules Learned from Analyst's Solution

1. The analyst extends the analysis logic

2. Disciple learns reasoning rules

Learned Rule

Disciple Agent KB

Assess whether there are states with nuclear weapons that may be willing to sell nuclear weapons to Al Qaeda.

Which is a nuclear state?
North Korea

Assess whether North Korea may be willing to sell nuclear weapons to Al Qaeda.

What might be a possible reason for North Korea to sell nuclear weapons to Al Qaeda?
United States is perceived as a common enemy of North Korea and Al Qaeda.

Assess to what extent the perception that United States is a common enemy of North Korea and Al Qaeda might be a good reason for North Korea to sell nuclear weapons to Al Qaeda.

DECOMPOSITION RULE DDR.00104 FORMAL DESCRIPTION

IF:	Assess whether there are states with nuclear weapons that may be willing to sell nuclear weapons to ?O1.

Q:	Which is a nuclear state?
A:	?O2

MAIN CONDITION

Var	Lower Bound	Upper Bound
?O1	(terrorist group)	(actor)
?O2	(nuclear state)	(nuclear state)

THEN:	Assess whether ?O2 may be willing to sell nu...

Learned Rule

DECOMPOSITION RULE DDR.00105

IF:	Assess whether ?O1 may be w...

Q:	What might be a poss... weapons to ?O2?
A:	?O3 is perceived as a...

MA

Var	Low...
?O1	(nu...
?O2	(terr...
?O3	(superpower, ...

Var	Relationship	Var
?O1	perceives as enemy	?O3
?O2	perceives as enemy	?O3

THEN:	Assess to what extent the perception that ?O3 is a common enemy of ?O1 and ?O2 might be a good reason for ?O1 to sell nuclear weapons to ?O2.

*To assess whether there are states that may be willing to sell nuclear weapons to an actor, **one has to consider each nuclear state** and assess whether that state may be willing to sell nuclear weapons to that actor.*

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P6. Multistrategy Learning

Develop multistrategy learning methods that integrate complementary learning strategies to take advantage of their strengths to compensate for each other's weaknesses

Knowledge Base

Learning by Analogy and Experimentation

Failure explanation

Example of problem reductions generated by the agent

Incorrect example

Correct example

Learning from Explanations

Learning from Examples

IF we have to solve **<Problem>**

Main PVS Condition

Except-When PVS Condition

Except-When PVS Condition

THEN solve **<Subproblem 1>** … **<Subproblem m>**

Rules Refined based on Analyst's Critique

1. Disciple applies the learned rule

2. The analyst critiques the reasoning

3. Disciple-LTA refines the rule with an except-when condition

This is wrong!

France will not sell nuclear weapons to Al Qaeda because it perceives it as an enemy.

Disciple Agent KB

Assess whether there are states with nuclear weapons willing to sell nuclear weapons to Al Qaeda.

Which is a nuclear state?
North Korea

Assess whether North Korea is willing to sell nuclear weapons to Al Qaeda

Which is a nuclear state?
France

Assess whether France is willing to sell nuclear weapons to Al Qaeda.

Which is a nuclear state?
India

Assess whether India is willing to sell nuclear weapons to Al Qaeda.

Which is a nuclear state?
Iran

Assess wh...

Which is a nuclear state?
Israel

Assess wh...

Which is a nuclear state?
Pakistan

Assess wheth...

*To assess whether there are states that may be willing to sell nuclear weapons to an actor, **one has to consider each nuclear state** and assess whether that state may be willing to sell nuclear weapons to that actor, **except for** the case in which the nuclear state is an enemy of that actor.*

Rule Viewer

Refined Rule — RULE DDR.00205 FORMAL

DESCRIPTION

IF:	Assess whether there are states with nuclear weapons willing to sell nuclear weapons to ?O1.

Q:	Which is a nuclear state?
A:	?O2

MAIN CONDITION

Var	Lower Bound	Upper Bound
?O1	(terrorist group)	(actor)
?O2	(nuclear state)	(nuclear state)

EXCEPT WHEN CONDITION 1

Var	Lower Bound	Upper Bound
?O2	(nuclear state)	(actor)
?O1	(terrorist group)	(actor)

Var	Relationship	Var
?O2	perceives as enemy	?O1

THEN:	Assess whether ?O2 is willing to sell nuclear weapons to ?O1.

Rules Refined based on Analyst's Critique

1. Disciple applies the refined rule

2. The analyst critiques the reasoning

3. Disciple refines the rule with a new except-when condition

Disciple Agent KB

This is wrong!

Russia will not sell nuclear weapons to Al Qaeda because it opposes the proliferation of nuclear weapons.

Assess whether there are states with nuclear weapons willing to sell nuclear weapons to Al Qaeda.

    Which is a nuclear state which is not an enemy of Al Qaeda? North Korea

        Assess whether North Korea is willing to sell nuclear weapons to Al Qaeda.

    Which is a nuclear state which is not an enemy of Al Qaeda? Iran

        Assess whether Iran is willing to sell nuclear weapons to Al Q

    Which is a nuclear state which is not an enemy of Al Qaeda? Pakistan

        Assess whether Pakistan is willing to sell nuclear weapons to

    Which is a nuclear state which is not an enemy of Al Qaeda? Russia

        Assess whether Russia is willing to sell nuclear weapons to A

*To assess whether there are states that may be willing to sell nuclear weapons to an actor, **one has to consider each nuclear state** and assess whether that state may be willing to sell nuclear weapons to that actor, **except for** the case in which the nuclear state is an enemy of that actor and also **except for** the case when the nuclear state opposes the proliferation of nuclear weapons.*

Refined Rule

DECOMPOSITION RULE DDR.00205 FORMAL DESCRIPTION

IF:	Assess whether there are states with nuclear weapons willing to sell nuclear weapons to ?O1.

Q:	Which is a nuclear state which is not an enemy of ?O1?
A:	?O2

MAIN CONDITION

Var	Lower Bound	Upper Bound
?O1	(terrorist group)	(actor)
?O2	(nuclear state)	(nuclear state)

EXCEPT WHEN CONDITION 1

Var	Lower Bound	Upper Bound
?O2	(nuclear state)	(actor)
?O1	(terrorist group)	(actor)

Var	Relationship	Var
?O2	perceives as enemy	?O1

EXCEPT WHEN CONDITION 2

Var	Lower Bound	Upper Bound
?O2	(nuclear state)	(actor)
?SI1	[medium - medium]	[very low - very high]

Var	Relationship	Var
?O2	degree of opposition to nuclear weapons proliferation	?SI1

ssess whether ?O2 is willing to sell nuclear weapons to ?O1.

© 20

Demo

**Disciple-LTA Demo:
Solving, Modeling, and Learning**

Discussion: Rule Refinement with Negative Example

Rule Condition C

• **Learn Except When Condition (C, Ex)**
• **Keep as Negative Exception (C, Ex)**

• **Keep as Negative Example (C, Ex)**
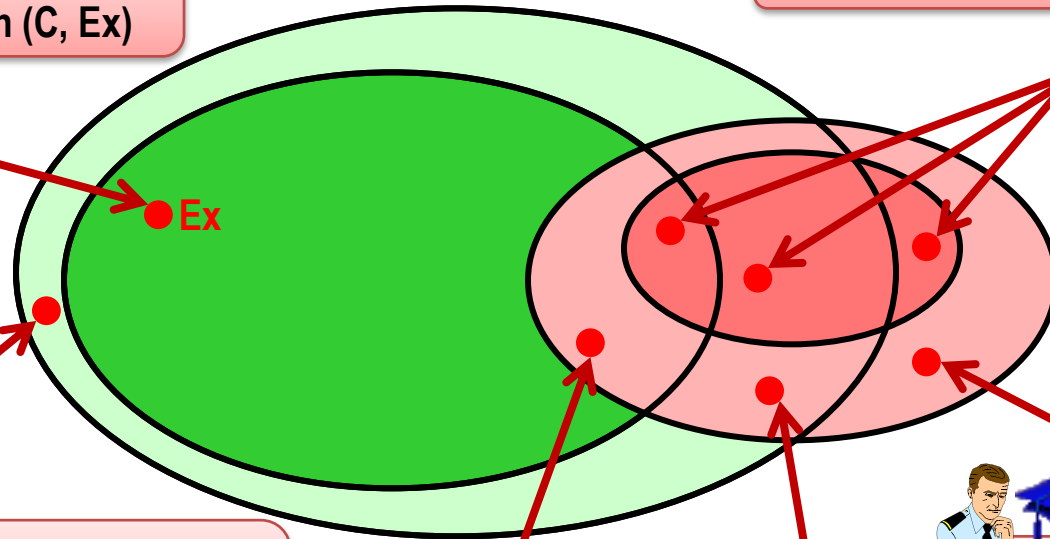
Ex

• **Specialize Upper Bound of Main Cond (C, Ex)**
• **Learn Except When Condition (C, Ex)**
• **Keep as Negative Exception (C, Ex)**

• **Generalize Lower Bound of Except When Condition (C, Ex)**

• **Generalize Lower Bound of Except When Cond (C, Ex)**
• **Learn Except When Condition (C, Ex)**
• **Keep as Negative Exception (C, Ex)**

• **Generalize Lower Bound of Except When Cond (C, Ex)**
• **Specialize Upper Bound of Main Cond (C, Ex)**
• **Learn Except When Condition (C, Ex)**
• **Keep as Negative Exception (C, Ex)**

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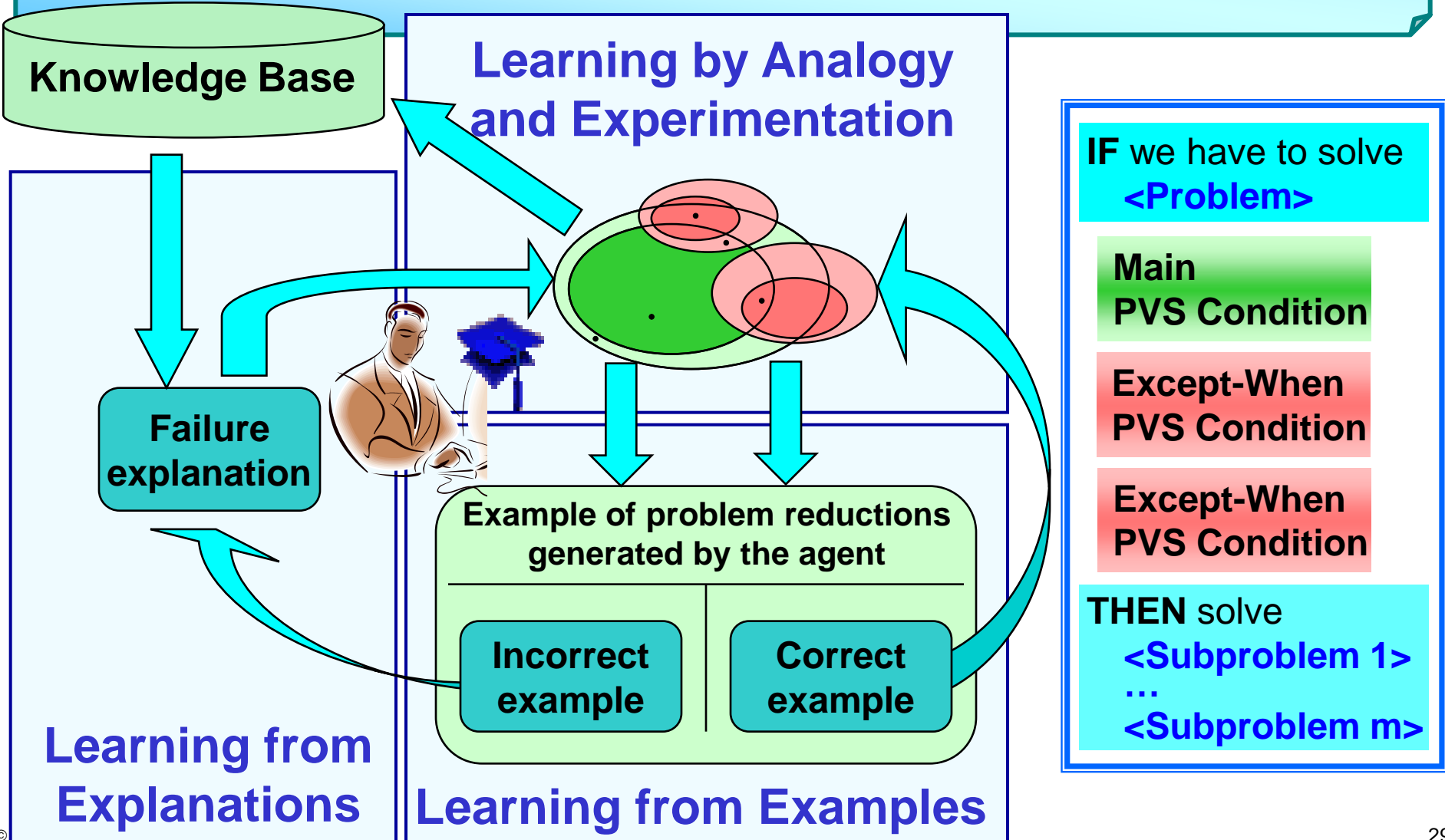Mixed-Initiative Modeling, Learning and Problem Solving

Plausible Reasoning with Partially Learned Knowledge

User Tutoring in Problem Solving

Agent Architecture for Generality-Power Tradeoff

Develop methods that allow continuous adaptation of the previously learned rules to the evolution of the ontology.

authoritative record evidence

testimonial evidence obtained at second hand

testimonial evidence

direct test ev

testimonial evidence as opinion based on analysis

type-based evidence

testimonial evidence based upon direct observation

testimonial evidence about tangible evidence

chart evidence

videotape evidence

audiotape evidence

tangible evidence

object evidence

IF <Problem>

PVS Condition

Except-When
PVS Condition

THEN   <Subproblem 1>
       …
       <Subproblem m>

PVS Condition

Except-When
PVS Condition
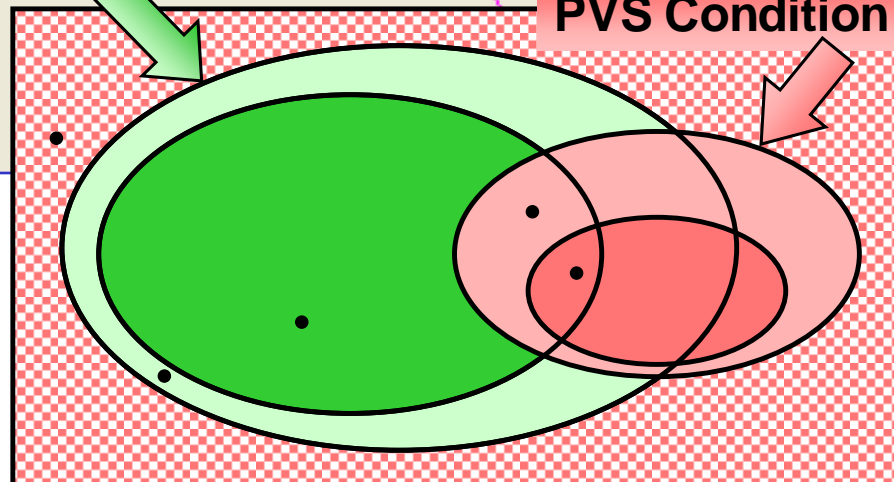
Characterization of the Disciple Learning Methods

Uses the explanation of the first positive example to generate a much smaller version space than the classical version space method.

Conducts an efficient heuristic search of the version space, guided by explanations, and by the maintenance of a single upper bound condition and a single lower bound condition.

Will always learn a rule, even in the presence of exceptions.

Learns from a few examples and an incomplete knowledge base.

Uses a form of multistrategy learning that synergistically integrates learning from examples, learning from explanations, and learning by analogy, to compensate for the incomplete knowledge.

Uses mixed-initiative reasoning to involve the expert in the learning process.

Is applicable to complex real-world domains, being able to learn within a complex and evolving representation language.

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P8. Mixed-Initiative Modeling, Learning and Pb. Solv.

Creative solution

Context for creative solution

Modeling

Mixed Initiative Reasoning

Generated example

Problem Solving

Refined rule

Expert example

Learning

Rule-based guidance

Develop mixed-initiative methods where modeling, learning, and problem solving mutually support each other.

Problem

Mixed-Initiative Problem Solving

Reasoning Tree

Extend Reasoning Tree

Accept Reasoning Steps

Reject Reasoning Steps

Explain Examples

Explain Examples

Explain Examples

Explain Examples

Rule Learning

Rule Refinement

Ontology + Rules

Learned Rules

Refined Rules

Refined Ontology

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P9. Plausible Reasoning with Partially Learned Knowledge

Develop reasoning methods based on confidence levels that allow efficient use of partially learned rules for modeling expert's reasoning, learning and problem solving.

PVS Condition

Except-When PVS Condition

Rule's conclusion is (most likely) incorrect

Rule's conclusion is not plausible

Rule's conclusion is (most likely) incorrect

Rule's conclusion is plausible

Rule's conclusion is (most likely) correct

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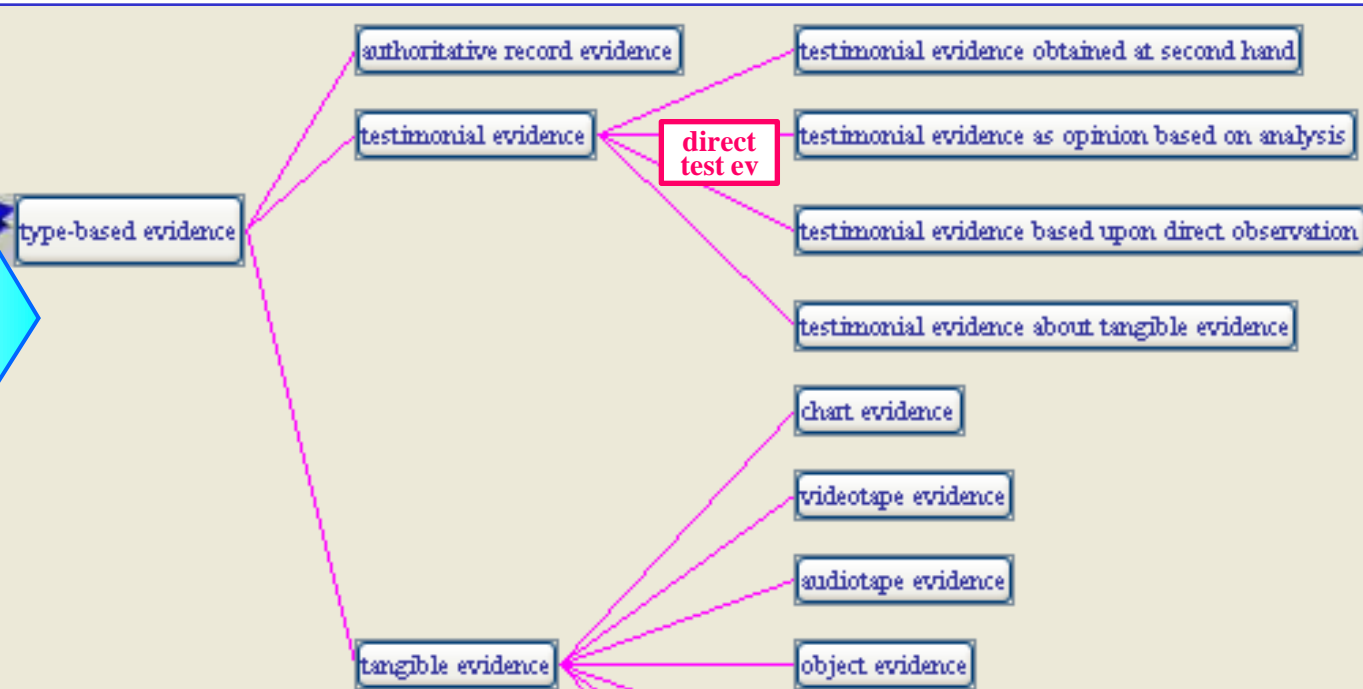Plausible Reasoning with Partially Learned Knowledge

User Tutoring in Problem Solving

Agent Architecture for Generality-Power Tradeoff

P10. User Tutoring in Problem Solving

Develop approaches to user tutoring that allow the agent to easily and rapidly teach the user its problem solving paradigm, to facilitate their collaboration.

Disciple-LTA Demo: Tutoring

Disciple Agent

KB

teaches

Lesson Fragment: Hypothesis support from a piece of evidence

Tutoring

Lesson: Hypothesis support from piece of evidence.

Assess to what extent the piece of evidence favors the hypothesis.

The information provided by the piece of evidence and the extent to which it is believable.

Assess to what extent the piece of evidence favors the hypothesis, assuming that we believe the information provided by the piece of evidence.

Assess the extent to which the information provided by the piece of evidence is believable.

The piece of evidence is testimonial evidence obtained at second hand.

The piece of evidence is testimonial evidence about tangible evidence.

The piece of evidence is direct testimonial evidence.

Assess the believability the reporter of the piece of evidence.

Assess the believability the source of the piece of evidence.

Assess the believability the reporter of the piece of evidence.

Assess the credibility of the tangible evidence.

Assess the believability the source of the piece of evidence.

Abstract reduction strategy

Illustrations: Previous   Next   Select Example: EVD-Dawn-Mir01-02c and Al Qaeda

Assess to what extent the piece of evidence EVD-Dawn-Mir01-02c favors the hypothesis that Al Qaeda considers deterrence as a reason to obtain nuclear weapons.

Q:What factors determine how a piece of evidence favors a hypothesis?
A:The information provided by the piece of evidence and the extent to which it is believable.

Assess to what extent EVD-Dawn-Mir01-02c favors the hypothesis that Al Qaeda considers deterrence as a reason to obtain nuclear weapons, assuming we believe the information provided by...

Assess the extent to which the information provided by EVD-Dawn-Mir01-02c is believable.

Q:How was EVD-Dawn-Mir01-02c obtained?
A:EVD-Dawn-Mir01-02c was obtained as testimonial evidence of Osama bin Laden cited in EVD-Dawn-Mir01-02 by Hamid Mir.

Assess the extent to which one can believe Hamid Mir as the reporter of EVD-Dawn-Mir01-02.

Assess the extent to which one can believe Osama bin Laden as the source of EVD-Dawn-Mir01-02c.

Lesson on Evidence

Automatically generated illustration of the abstract strategy

Lesson Fragment: Hypothesis support from a piece of evidence

Abstract synthesis strategy

Automatically generated illustration of the abstract strategy

Tutoring

Assess to what extent the piece of evidence favors the hypothesis.

Assessed **support of hypothesis** from the piece of evidence.

If either the **support of the hypothesis** from the information in the piece of evidence is low or the **believability of the information** is low, then the overall support provided by the piece of evidence is low. Therefore we estimate the overall support of the hypothesis from the piece of evidence as the minimum between the **support of the hypothesis** from the information in the piece of evidence and the **believability of the information**.

Assess to what extent the piece of evid... assuming that we believe the informatio... evidence.

...iece of evidence is believable.

Assessed **believability of the information** provided by the piece of evidence.

Assessed **support of the hypothesis** from the information in the piece of evidence.

For testimonial evidence obtained at second hand to be believable, both the source and the reporter have to be believable. Therefore we estimate the **believability of the information** provided by the piece of evidence as the minimum between the **believability of the reporter** and the **believability of the source** of the piece of evidence.

The piece of evidence is testimonial evidence about tangible evidence.

We can believe a testimonial evidence about tangible evidence if we believe the reporter and if the tangible evidence is credible. Therefore we estimate the **believability of the information** provided by the piece of evidence as the minimum between the **believability of the reporter** and the credibility of the piece of evidence.

The piece of evidence is direct testimonial evidence.

The **believability of the information** provided by a direct testimonial evidence is given by the **believability of the source** of the piece of evidence.

Asse... the p...

Asse the p...

As... re...

Assessed **believability of the reporter** of the piece of evidence.

Assessed **believability of the source** of the piece of evidence.

Illustrations: Previous   Next   **Select Example:**   EVD-Dawn-Mir01-02c and Al Qaeda

Assess to what extent the piece of evidence EVD-Dawn-Mir01-02c favors the hypothesis that Al Qaeda considers deterrence as a reason to obtain nuclear weapons.

Based on EVD-Dawn-Mir01-02c, it is an even chance that Al Qaeda considers deterrence as a reason to obtain nuclear weapons.

A: The information provided by the piece of evidence and the extent to which it is believable.

Assess to what extent EVD-Dawn-Mir01-02c favors the hypothesis that Al Qaeda considers deterrence as a reason to obtain nuclear weapons, assuming that we believe the information provided by EVD-Dawn-Mir01-02c.

Based only on the information from EVD-Dawn-Mir01-02c, it is almost certain that Al Qaeda considers deterrence as a reason to obtain nuclear weapons.

Assess the extent to which the information provided by EVD-Dawn-Mir01-02c is believable.

It is an even chance that the information provided by EVD-Dawn-Mir01-02c is believable.

Q: How was EVD-Dawn-Mir01-02c obtained?
A: EVD-Dawn-Mir01-02c was obtained as testimonial evidence of Osama bin Laden cited in EVD-Dawn-Mir01-02 by Hamid Mir.

Assess the extent to which one can believe Hamid Mir as the reporter of EVD-Dawn-Mir01-02.

It is almost certain that Hamid Mir is believable as the reporter of EVD-Dawn-Mir01-02.

Assess the extent to which one can believe Osama bin Laden as the source of EVD-Dawn-Mir01-02c.

It is an even chance that Osama bin Laden is believable as the source of EVD-Dawn-Mir01-02c.

Overview: Design Principles

Spiral Development with SMEs and End-Users

Problem Solving Paradigm for User-Agent Collaboration

Multi-Agent and Multi-Domain Problem Solving

Knowledge Base Structuring for Knowledge Reuse

Integrated Teaching and Learning

Multistrategy Learning
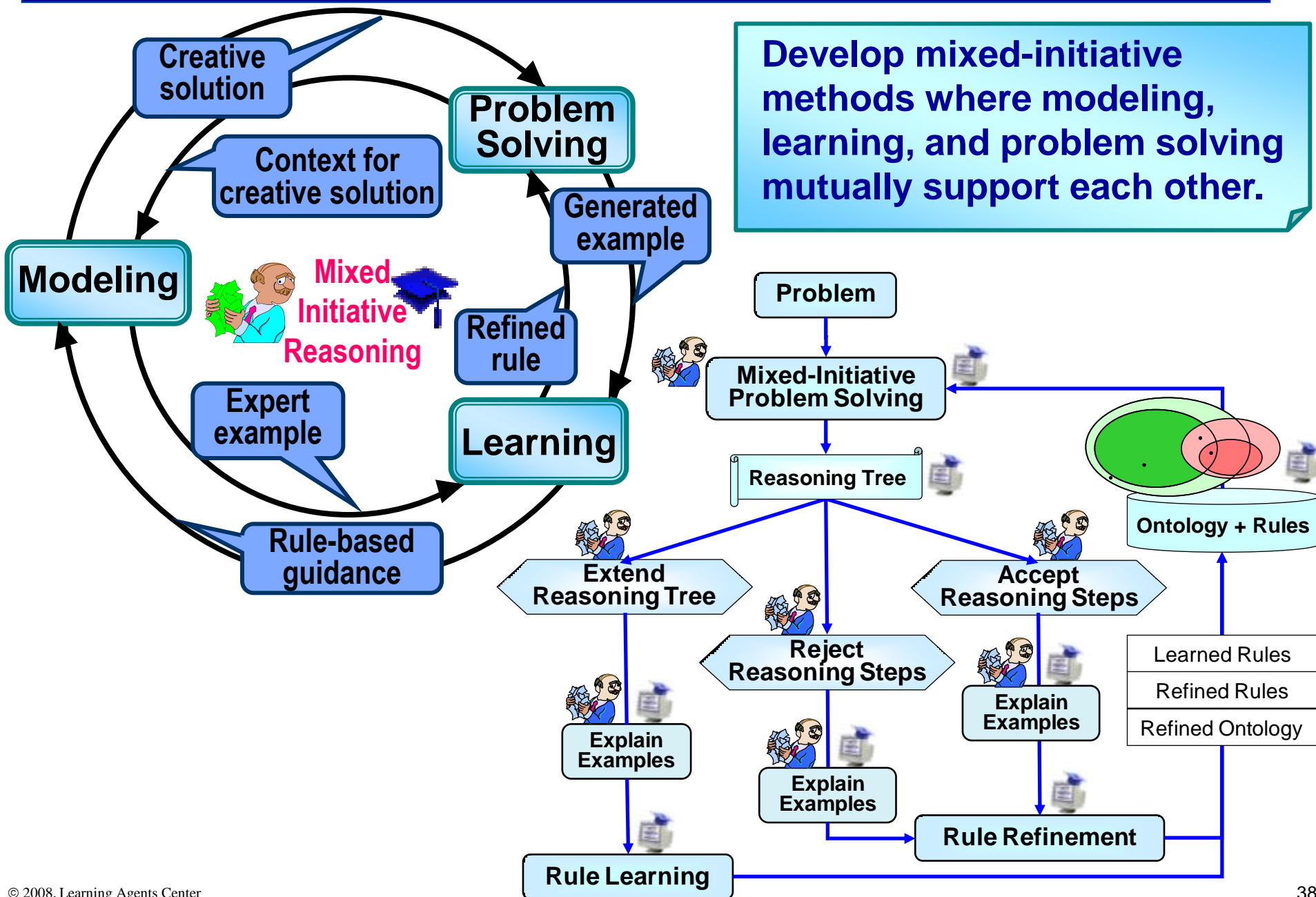
Learning with an Evolving Representation Space

Mixed-Initiative Modeling, Learning and Problem Solving

Plausible Reasoning with Partially Learned Knowledge
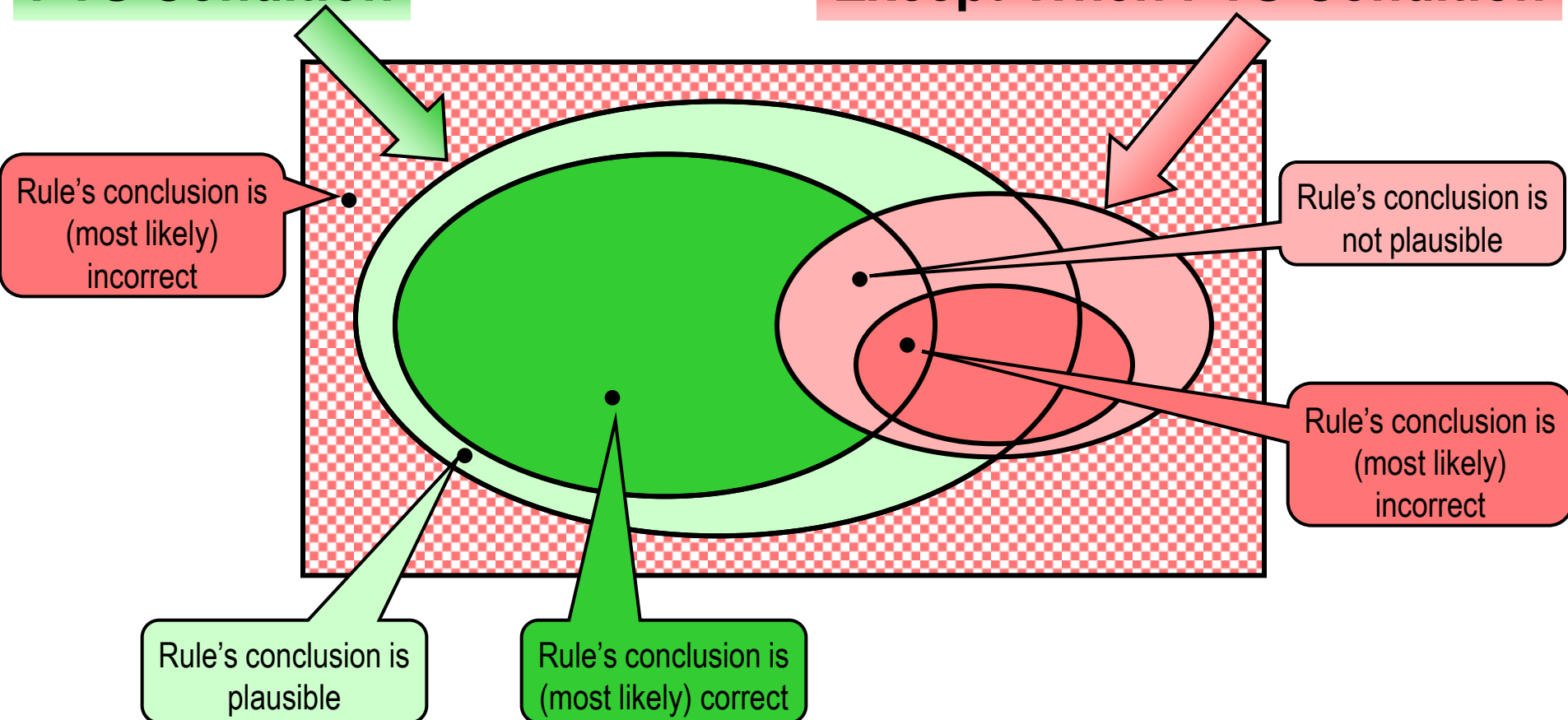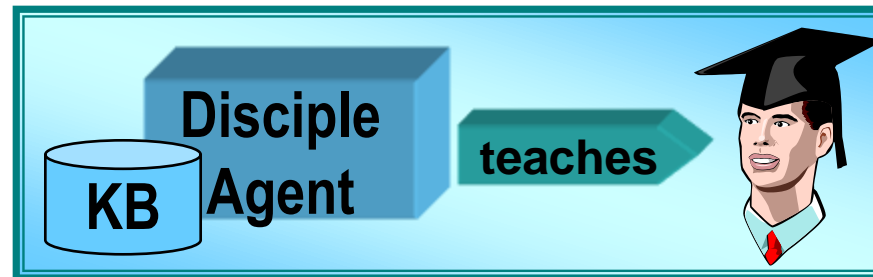
User Tutoring in Problem Solving

Agent Architecture for Generality-Power Tradeoff

P11: Architecture for Generality-Power Tradeoff

Structure the architecture of the agent into two parts:
o a reusable domain-independent learning agent shell;
o domain specific modules.

Disciple Agent

Disciple Learning Agent Shell

| Graphical User Interface | Customized User Interface |

| Learner | Problem Solver | Customized Problem Solver |

Knowledge Repository

| Knowledge Base Manager | Knowledge Base |

Domain Independent Modules

Domain Dependent Modules
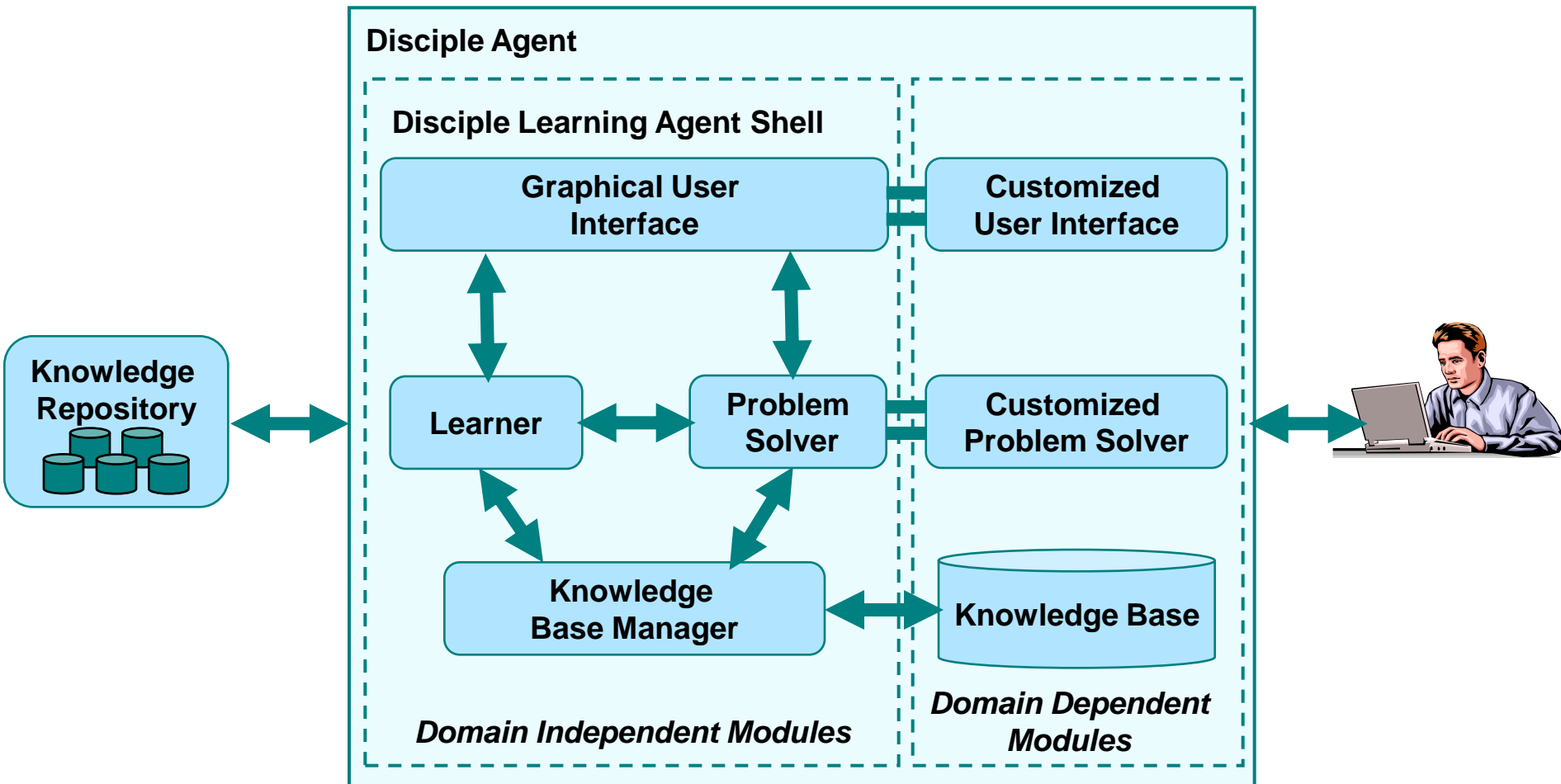
Overall Architecture of the Disciple Shell

Disciple Learning Agent Shell

Ontology Elicitation, Learning and Refinement

- Ontology Viewers and Editors
- Ontology Graphical Browsers
- Scenario Elicitation, Script Editor
- Ontology Learning and Refining

Mixed-initiative, Multi-agent Framework

- Multi-Agent Framework
- Mixed-Initiative Reasoner
- Task Agenda Modules
- Interaction Model Learning and Refining

Problem Solving

- Problem Solving Modules
- Assumptions Modules

Rule Learning and Refinement

- Task and Rule Learning Modules
- Plausible Explanation Generation Modules
- Rule Refinement Modules
- Rule Analysis Modules
- Control Wizards for Rule Refinement

Knowledge Integration, Import, and Export

- Knowledge Integration Tools
- Import Tools
- Export Tools

Knowledge Management, Verification and Validation

- Knowledge Management Module
- System Verification Modules
- Knowledge Base Validation Modules

Knowledge Repository Management

- Management of Distributed Knowledge Repository
- Knowledge Base Versioning

Customization of the Disciple Shell

Customization for each type of user

Subject Matter Expert

Field Application

Education and training

Disciple COG

Customization for each domain

Disciple Learning Agent Shell

Ontology Elicitation, Learning and Refinement

- Ontology Viewers and Editors
- Ontology Graphical Browsers
- Scenario Elicitation, Script Editor
- Ontology Learning and Refining

Mixed-initiative, Multi-agent Framework

- Multi-Agent Framework
- Mixed-Initiative Reasoner
- Task Agenda Modules
- Interaction Model Learning and Refining

Rule Learning and Refinement

- Task and Rule Learning Modules
- Plausible Explanation Generation Modules
- Rule Refinement Modules
- Rule Analysis Modules
- Control Wizards for Rule Refinement

Problem Solving

- Problem Solving Modules
- Assumptions Modules

Knowledge Integration, Import, and Export

- Knowledge Integration Tools
- Import Tools
- Export Tools

Knowledge Management, Verification and Validation

- Knowledge Management Module
- System Verification Modules
- Knowledge Base Validation Modules

Knowledge Repository Management

- Management of Distributed Knowledge Repository
- Knowledge Base Versioning

COG Report Generator

Dedicated modules

System knowledge base

Domain knowledge base

Conclusion: Research Vision for Learning Assistants