CS 681 Fall 2008
Designing Expert Systems

Knowledge-Based Reasoning: Part I

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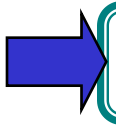
Overview



Types of Problems for Expert Systems

General Problem Solving Paradigms

Hands on Disciple-LTA: Intelligence Analysis

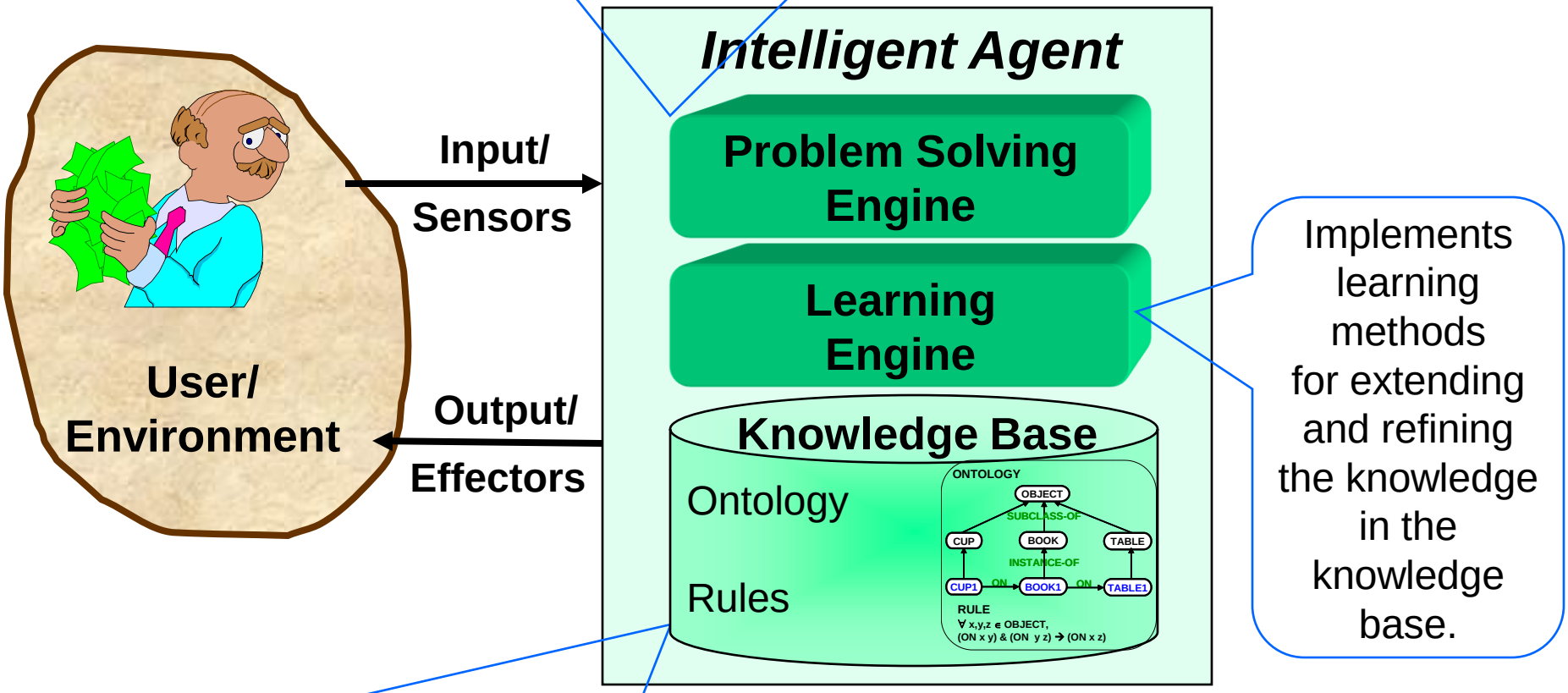
Website Believability as Expertise Problem

Reading

Overall Architecture of an Agent

Implements a general problem solving method that uses the knowledge from the knowledge base to interpret the input and provide an appropriate output.

Typical algorithms (e.g. sorting) use only input data (e.g. data to be sorted) and not domain-specific knowledge.



Implements learning methods for extending and refining the knowledge in the knowledge base.

Data structures that represent the objects from the application domain, general laws governing them, actions that can be performed with them, etc.

Types of Problems for Expert Systems

Diagnosis: Inferring system malfunctions from observables.

Monitoring: Comparing observations to expected outcomes.

Critiquing: Expressing judgments about something according to certain standards.

Types of Problems for Expert Systems

Diagnosis: Inferring system malfunctions from observables.

- Determining the disease of a patient from the observed symptoms.
- Locating faults in electrical circuits.
- Finding defective components in the cooling system of nuclear reactors.

Monitoring: Comparing observations to expected outcomes.

- Monitoring instrument readings in a nuclear reactor to detect accident conditions.
- Assisting patients in an intensive care unit by analyzing data from the monitoring equipment.

Critiquing: Expressing judgments about something according to certain standards.

- Critiquing a military course of action (or plan) based on the principles of war and the tenets of Army operations.

Types of Problems for Expert Systems

Design: Configuring objects under constraints.

Planning: Finding a set of actions that achieve a certain goal.

Repair: Executing plans to administer prescribed remedies.

Types of Problems for Expert Systems

Design: Configuring objects under constraints.

- Designing integrated circuits layouts.

Planning: Finding a set of actions that achieve a certain goal.

- Determine the actions that need to be performed in order to repair a bridge.

Repair: Executing plans to administer prescribed remedies.

- Tuning a mass spectrometer, i.e., setting the instrument's operating controls to achieve optimum sensitivity consistent with correct peak ratios and shapes.

Types of Problems for Expert Systems

Interpretation: Inferring situation description from sensory data.

Simulation: Representation of the operation or features of one process or system through the use of another.

Prediction: Inferring likely consequences of given situations.

Sample Problem Solving Tasks for Expert Systems

Interpretation: Inferring situation description from sensory data.

- Interpreting gauge readings in a chemical process plant to infer the status of the process.

Simulation: Representation of the operation or features of one process or system through the use of another.

- Simulation of a thermostat-controlled heating system to perform a qualitative behavior analysis.
- Simulation of production systems for bottleneck analysis.

Prediction: Inferring likely consequences of given situations.

- Predicting the damage to crops from some type of insect.
- Estimating global oil demand from the current geopolitical world situation.

Types of Problems for Expert Systems

Control: Governing overall system behavior.

- Managing the manufacturing and distribution of computer systems.

Debugging: Prescribing remedies for malfunctions.

- Determining how to tune a computer system to reduce a particular type of performance problem.

Repair: Executing plans to administer prescribed remedies.

- Choosing a repair procedure to fix a known malfunction in a locomotive.

Types of Problems for Expert Systems

Instruction: Diagnosing, debugging, and repairing student behavior.

- Teaching students a foreign language.
- Teaching students to troubleshoot electrical circuits.
- Teaching medical students in the area of antimicrobial therapy selection.

Any useful expert task:

Intelligence analysis

Information fusion.

Information assurance.

Travel planning.

Email management.

Choosing a PhD advisor, or a university.

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General Problem Solving Paradigms

- State-space search;
- Problem reduction and solution synthesis;
- Case-based reasoning / analogy;
- Bayesian networks.

The State Space Representation of a Problem

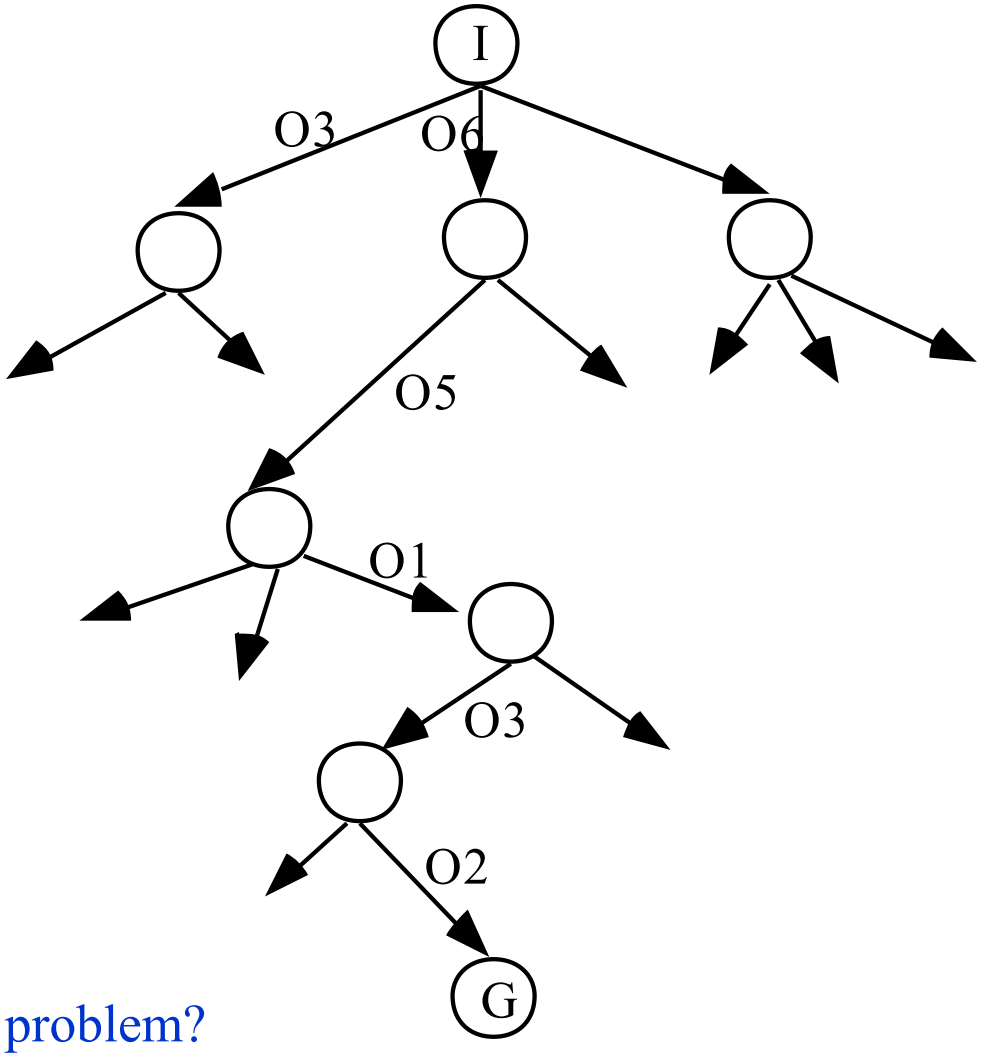
A problem is represented by a triple (I, O, G) where:

I - initial state,

O - a set of operators on states (successor function),

G - goal states.

A solution to the problem is a finite sequence of applications of operators that changes the initial state into a goal state.

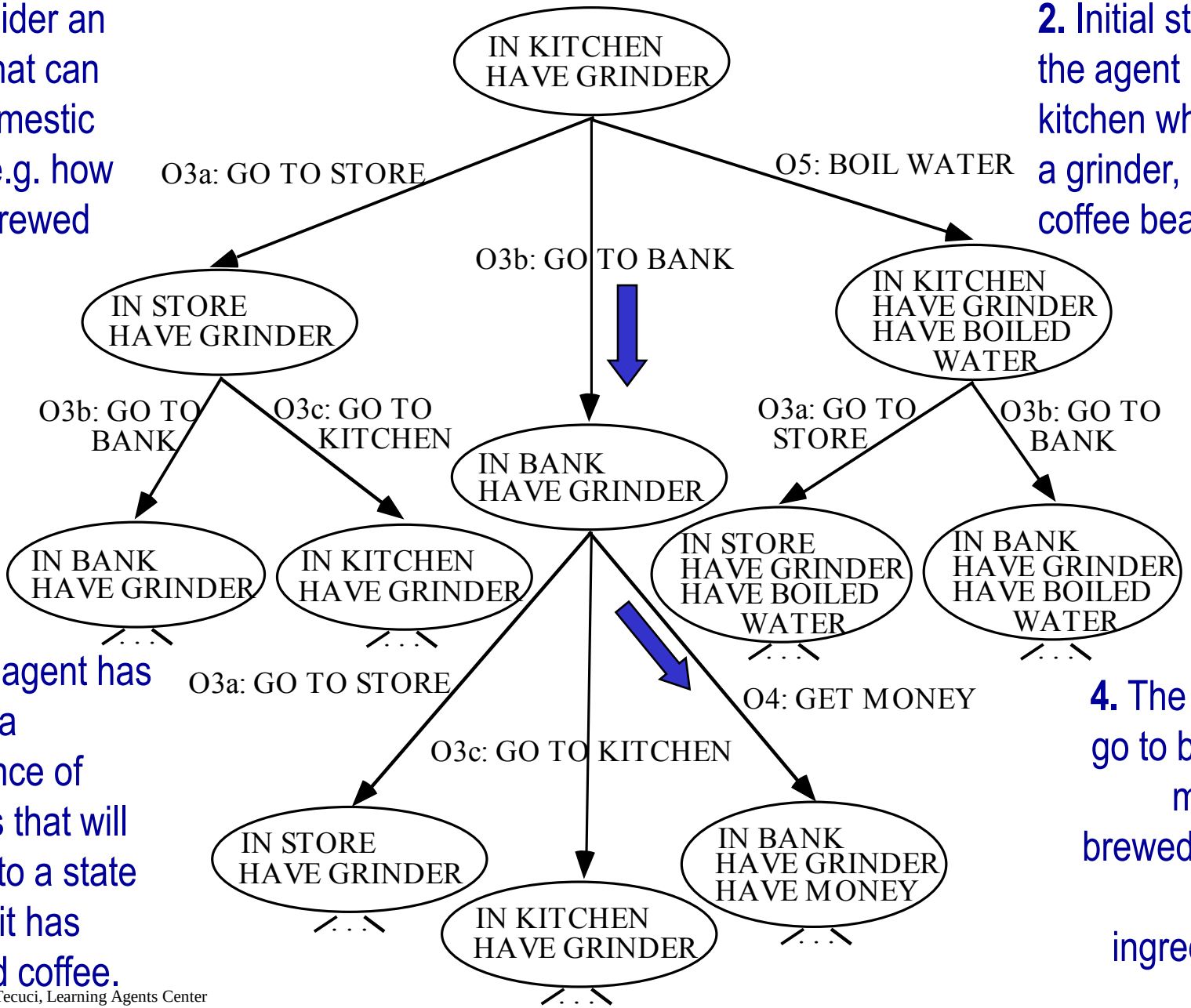


Which is a solution for this (I, O, G) problem?

Illustration: Search Space of a Planning Agent

1. Consider an agent that can plan domestic tasks (e.g. how to get brewed coffee).

2. Initial state: the agent is in the kitchen where it has a grinder, but no coffee beans.



3. The agent has to find a sequence of actions that will lead it to a state where it has brewed coffee.

4. The agent can go to bank to get money, buy brewed coffee, or buy the ingredients and make it.

The Reduction Representation of a Problem

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

P - the class of problems;

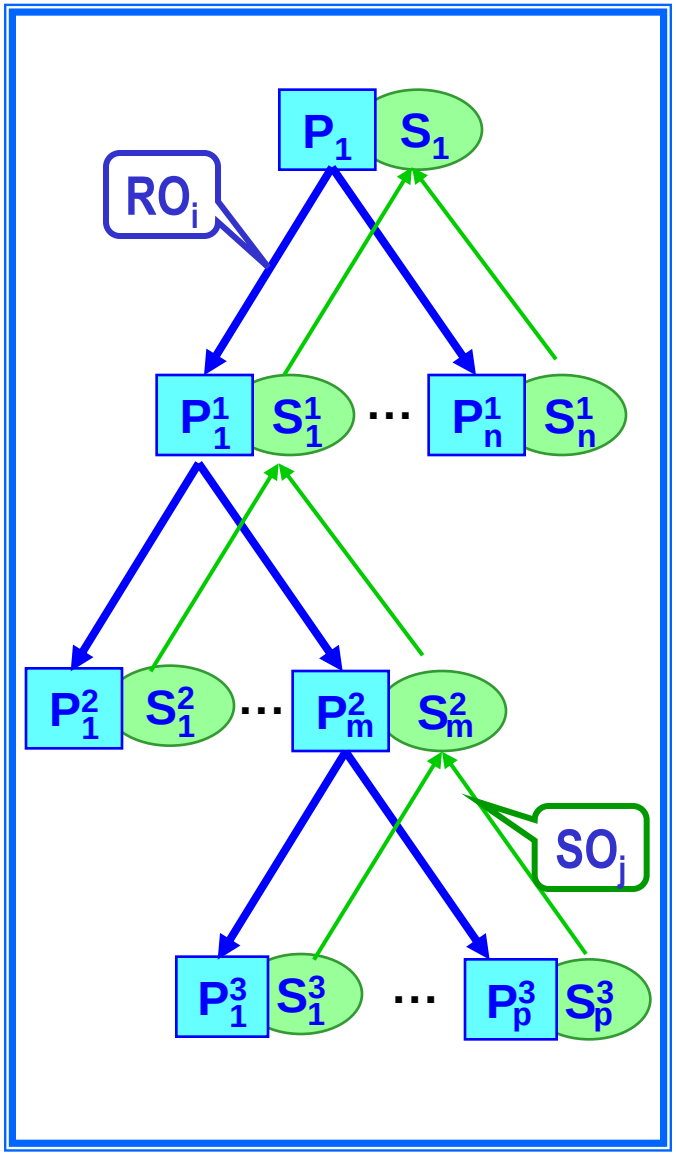
S - solutions;

RO - reduction operators that reduce a problem to sub-problems and/or solutions,

SO - synthesis operators that synthesize the solution of a problem from the solutions of its sub-problems.

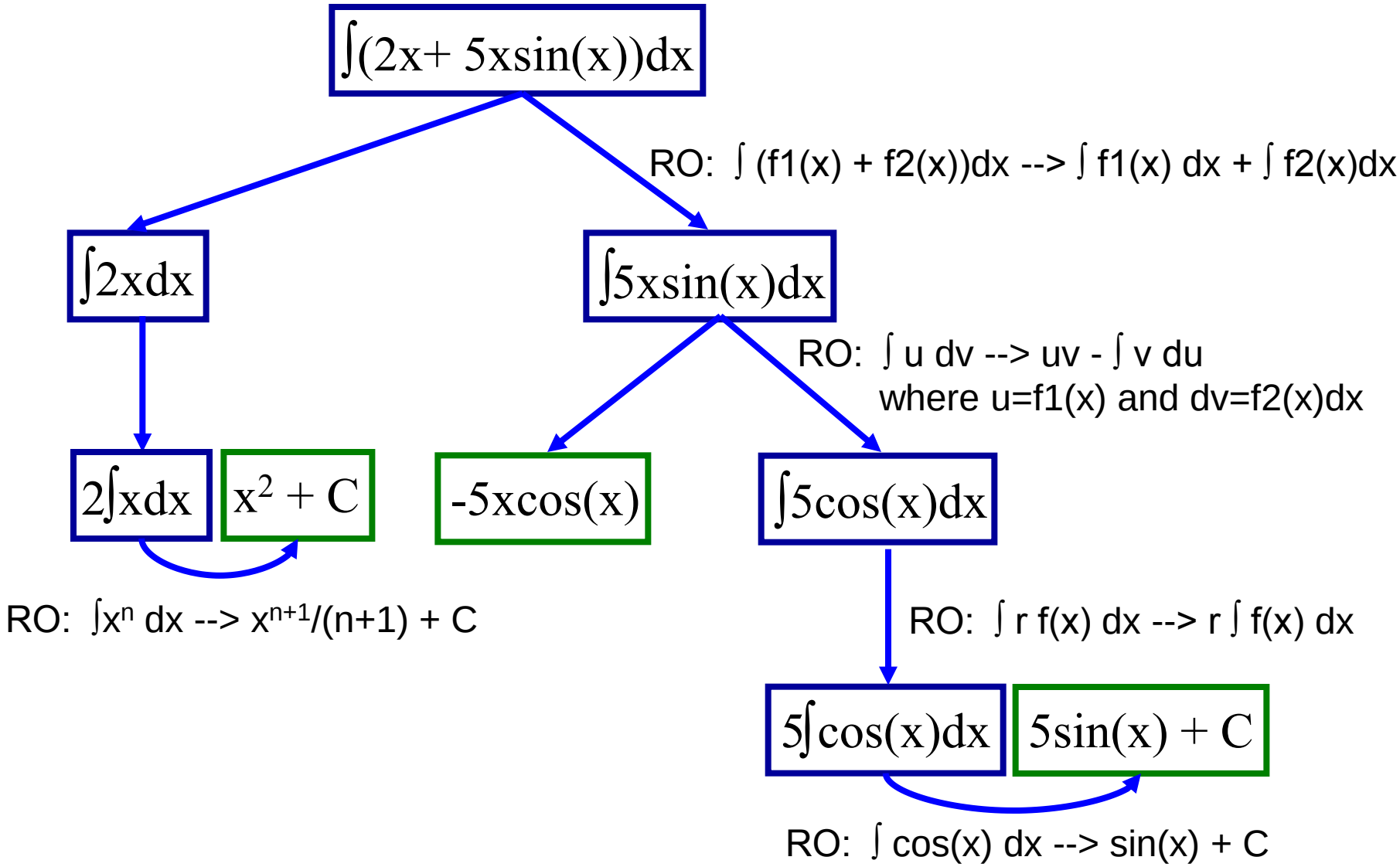
A problem P_1 is solved by:

- 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.



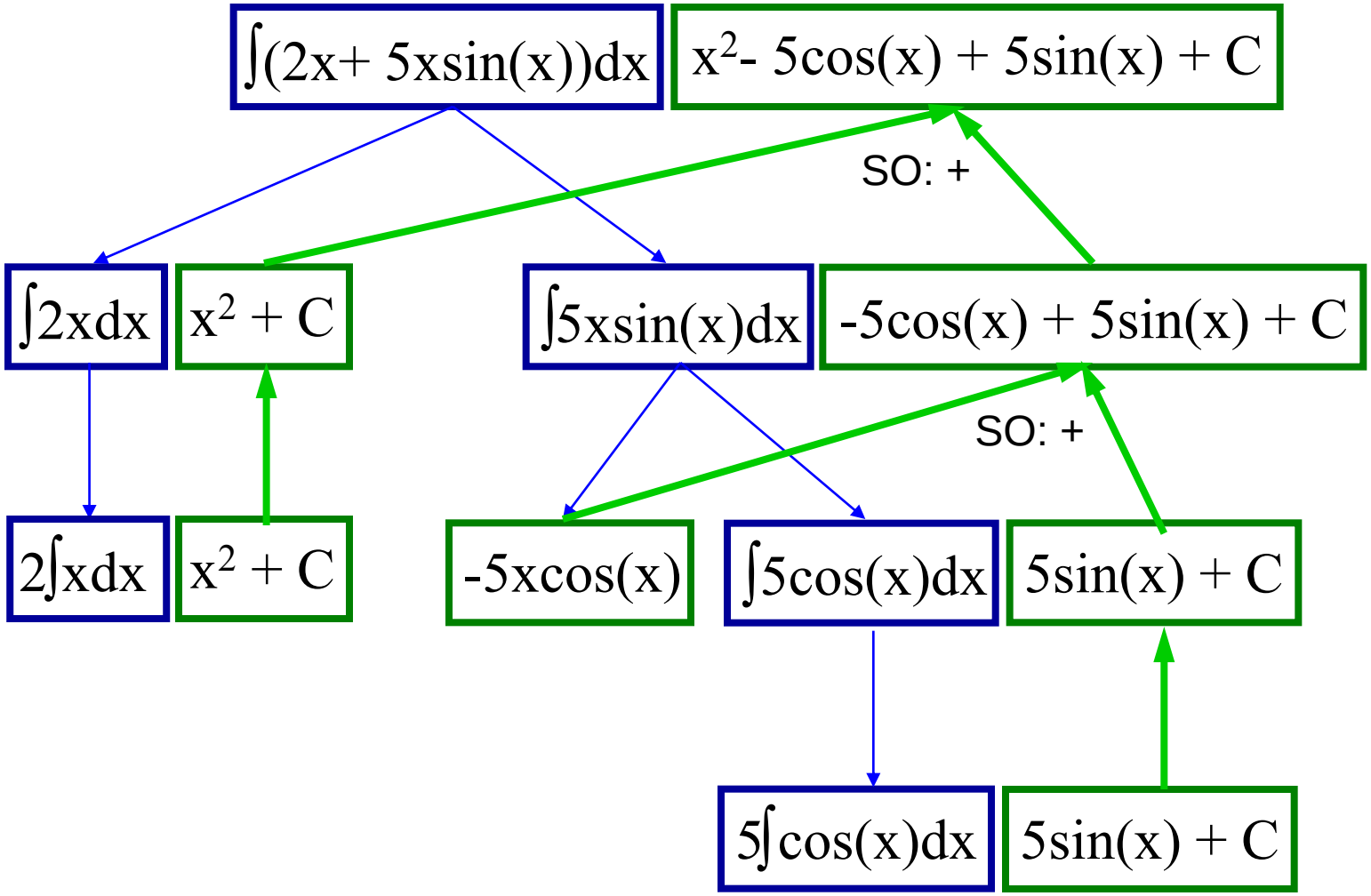
Reduction Representation of a Problem

Symbolic Integration: Problem Reduction

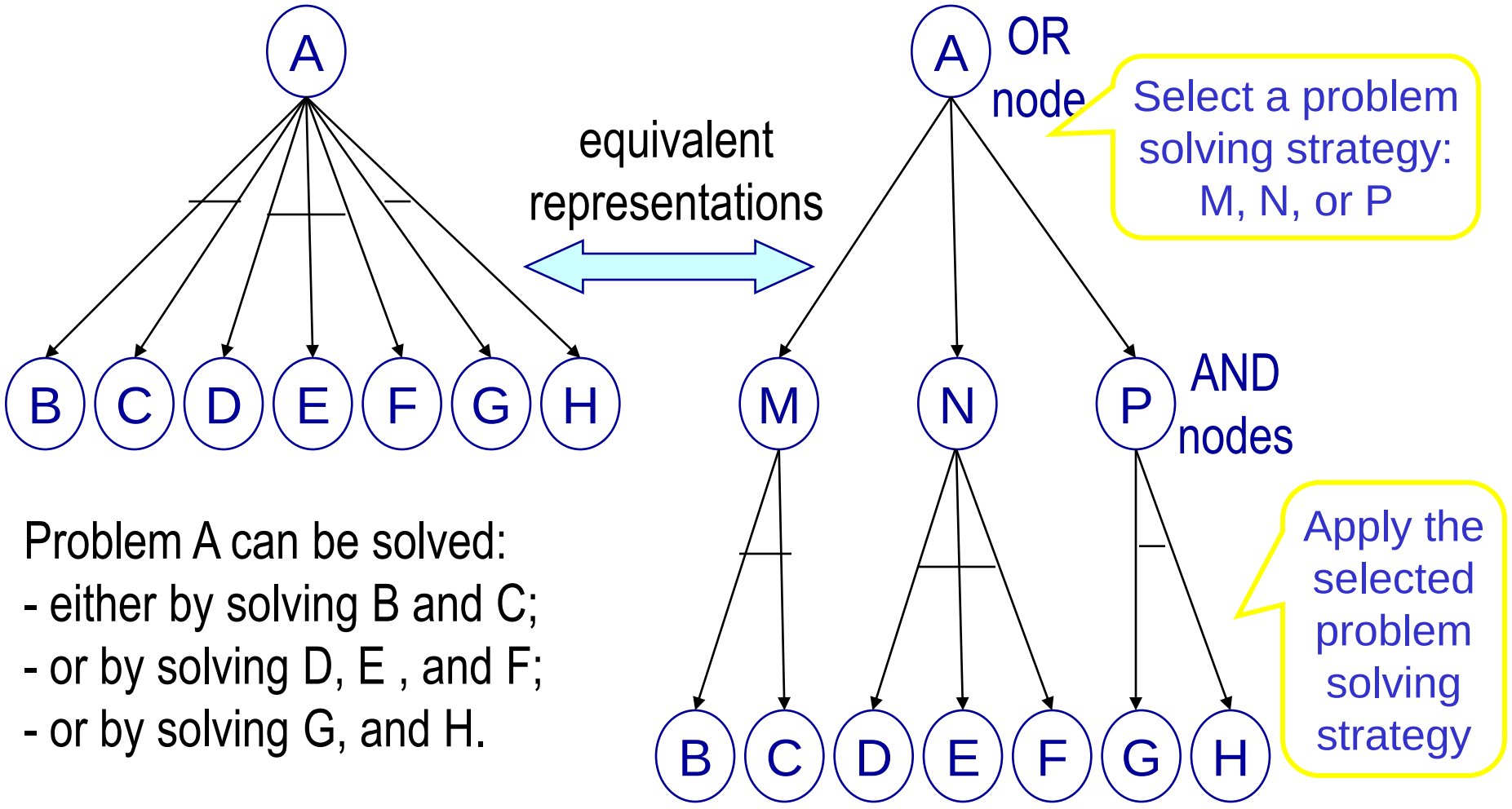


Problem Reduction Representation of a Problem

Symbolic Integration: Solution Synthesis



AND-OR Graphs



Problem A can be solved:
- either by solving B and C;
- or by solving D, E , and F;
- or by solving G, and H.

Problem Reduction based Question-Answering

General problem solving paradigm:
- natural for the human user;
- appropriate for the automated agent.

The reductions and synthesis operations are guided by introspective questions and answers.

"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

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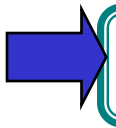
General Problem Solving Paradigms



Hands on Disciple-LTA: Intelligence Analysis

Website Believability as Expertise Problem

Reading

Intelligence Analysis as an Expertise Task

Analysis: Identifying the parts of a whole and their relations in making up the whole

The purpose of intelligence analysis is to analyze available partial and uncertain information in order to estimate the likelihood of one possible outcome, given the many possibilities in a particular scenario.

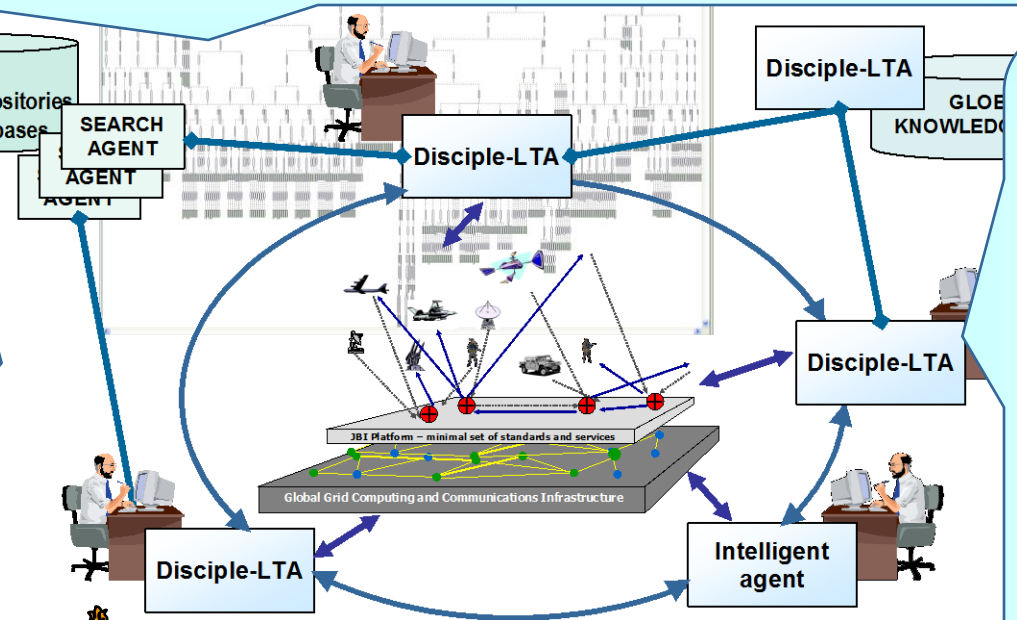
Disciple-LTA: Analyst's Cognitive Assistant

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.

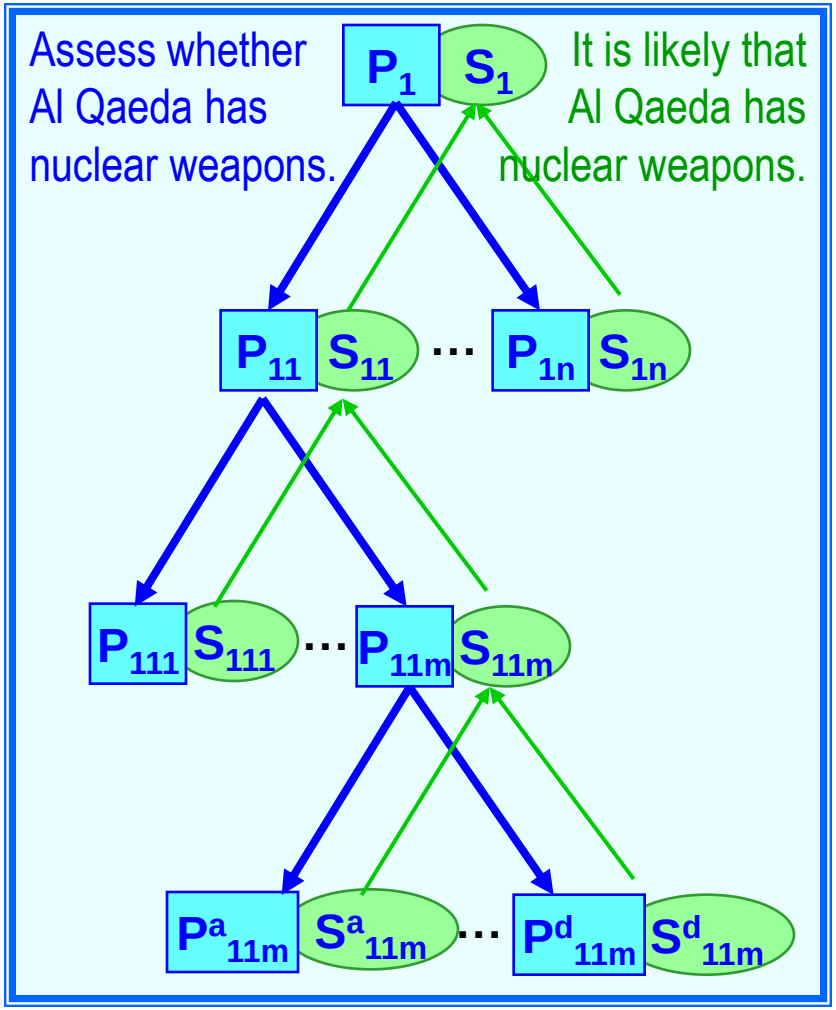
Hypothesis Analysis through Problem Reduction

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

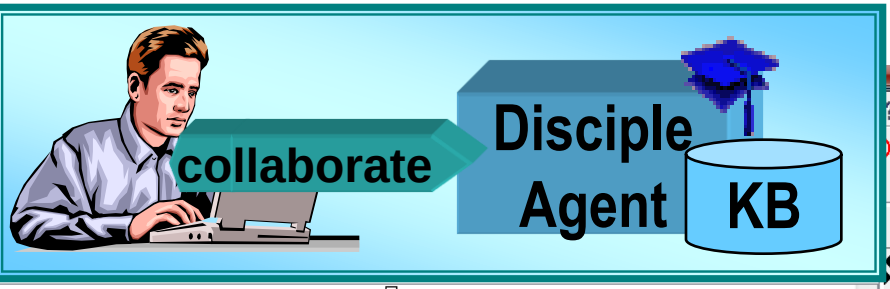
2) Potentially relevant pieces of evidence for the unsolved problems are identified.

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

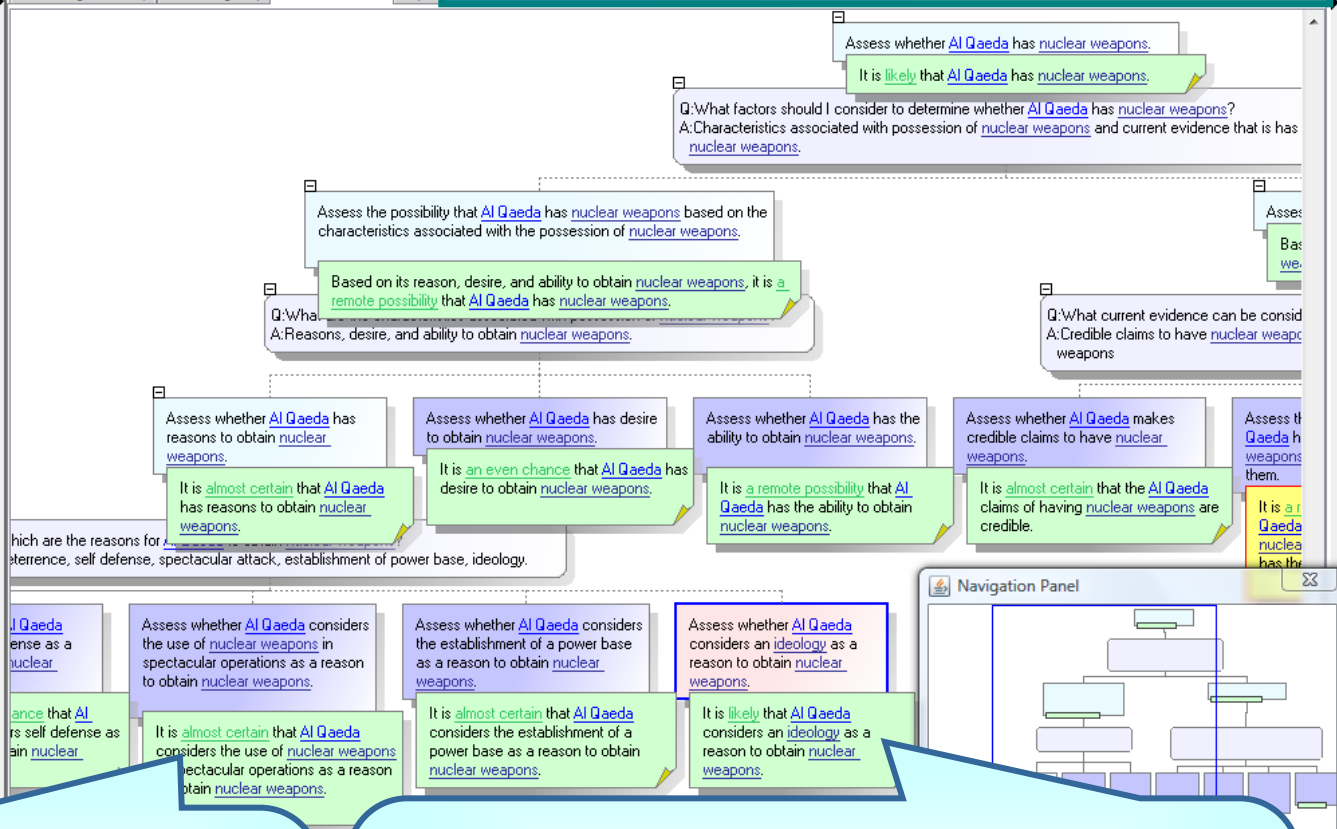
4) The solutions of the simplest problems are successively combined to obtain the solution of the initial problem.



Disciple-LTA Demo



Assess whether Al Qaeda has nuclear weapons: likely
- Deterrence as reason: an even chance
- Self defense as reason: an even chance
- Spectacular operations as reason: almost certain
- Establishment of power base as reason: almost certain
- Ideology as reason: likely
  - radical Islamic religious fundamentalist ideology as reason: likely
    - Favoring evidence: likely
      - EVD-Time-01-01c: an even chance
      - EVD-TRC-Najm01-01c: likely
        - Relevancy: almost certain
        - Believability: likely
          - Reporter Najm S: likely
          - Source Osama bin Laden: almost certain
            - Competency: almost certain
            - Credibility: almost certain
              - Veracity: almost certain
              - Objectivity: almost certain
              - Analytical ability: almost certain
    - Disfavoring evidence: no evidence
- Desire to obtain nuclear weapons: an even chance
- Ability to obtain nuclear weapons: a remote possibility
- Credible Al Qaeda claims to have nuclear weapons: almost certain

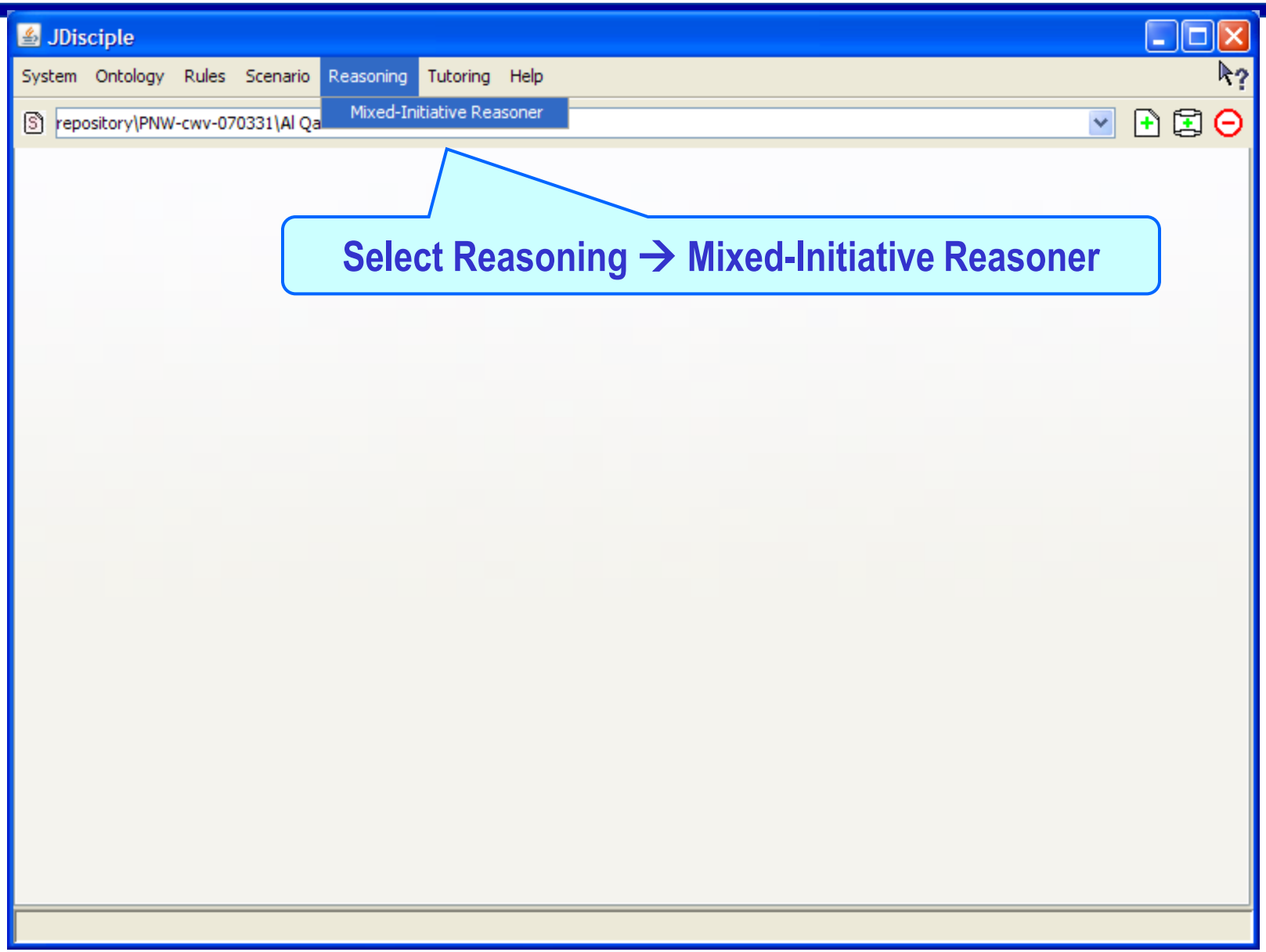


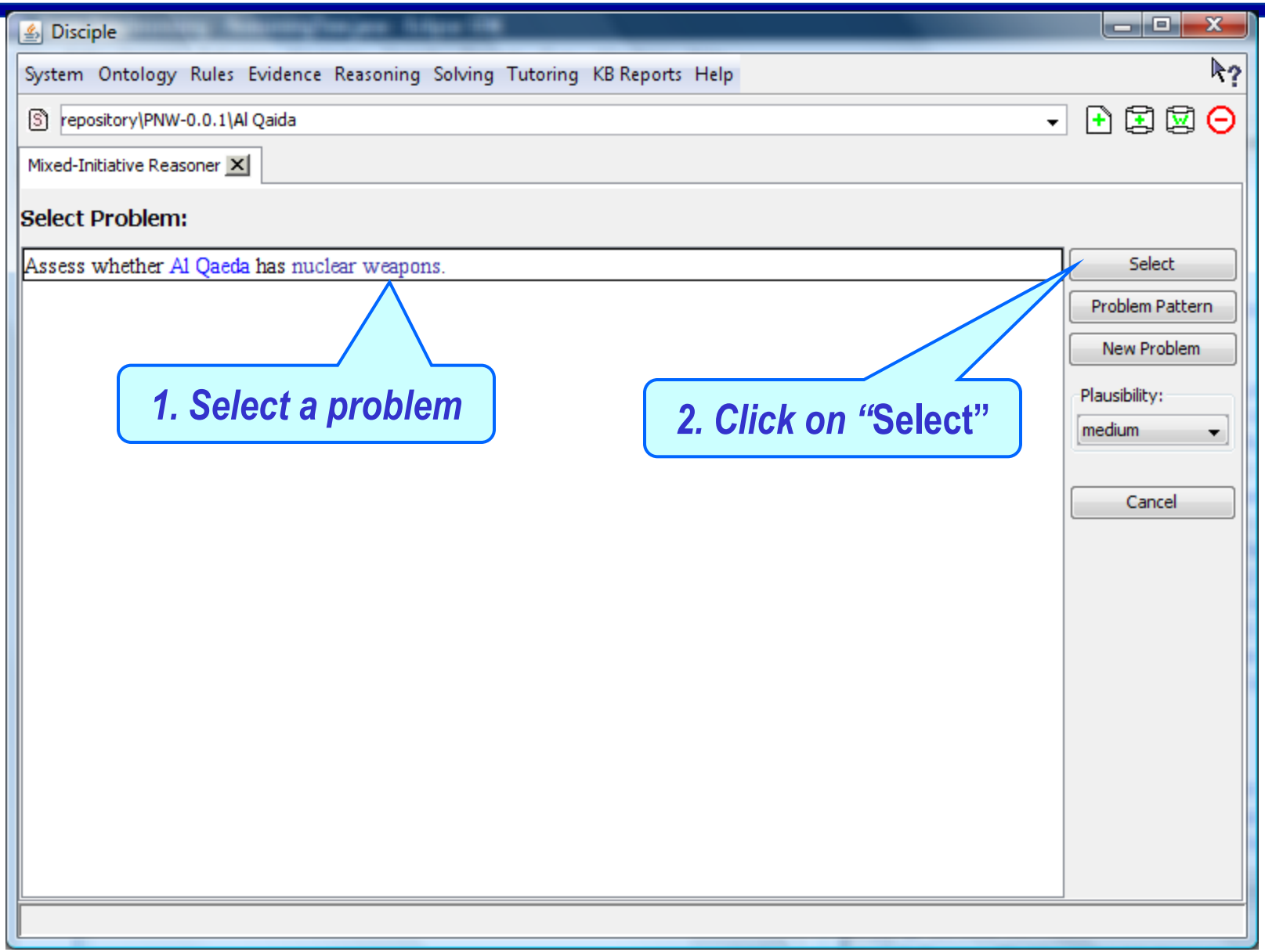
Makes very clear:

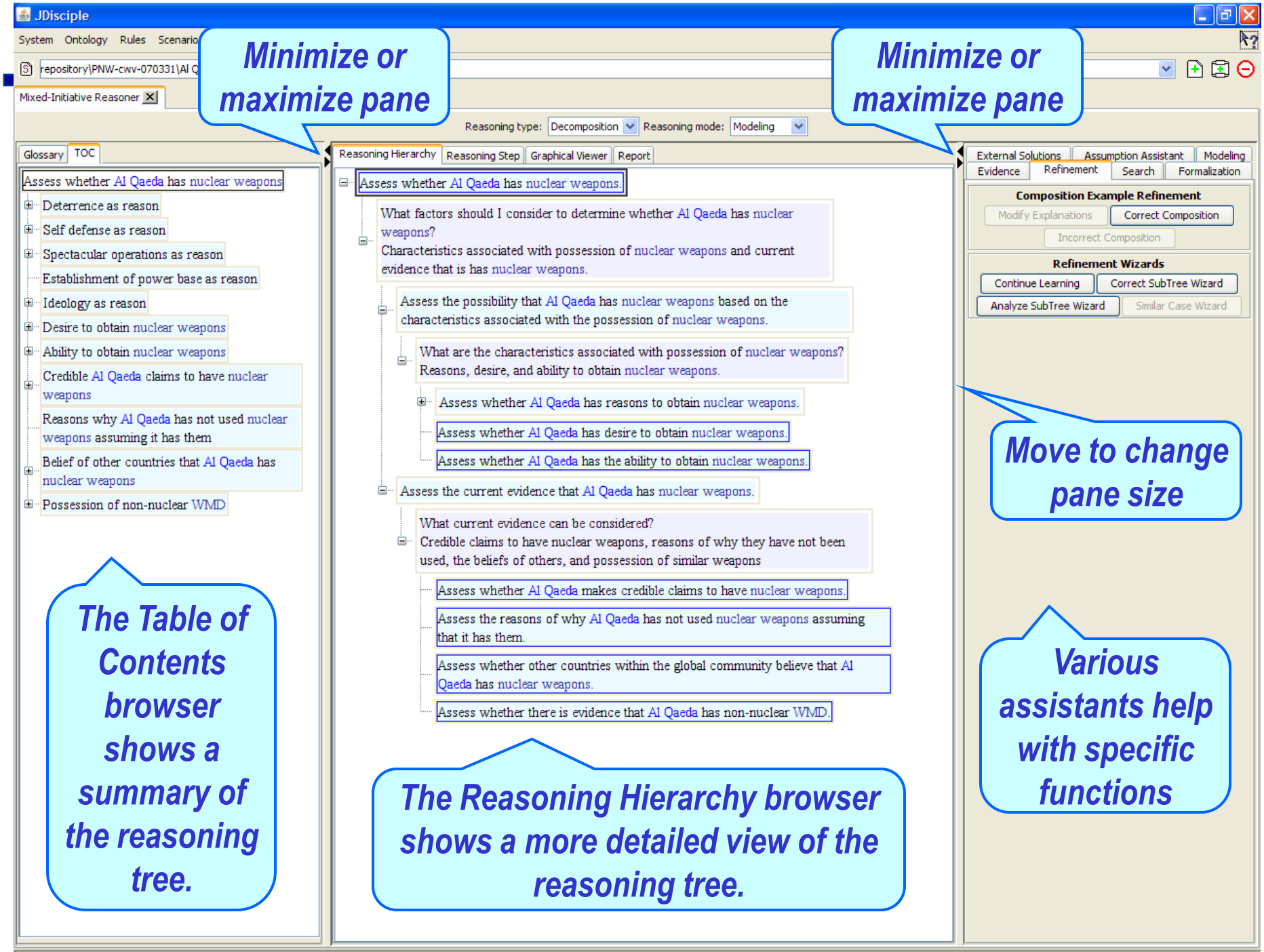
- The analysis logic;
- What evidence was used and how;
- What assumptions have been made;
- What is not known.

Allows for:

- Assumptions checking;
- What-if scenarios;
- Rapid updating of the analysis based on new intelligence data and assumptions.






JDisciple
System Ontology Rules Scenario
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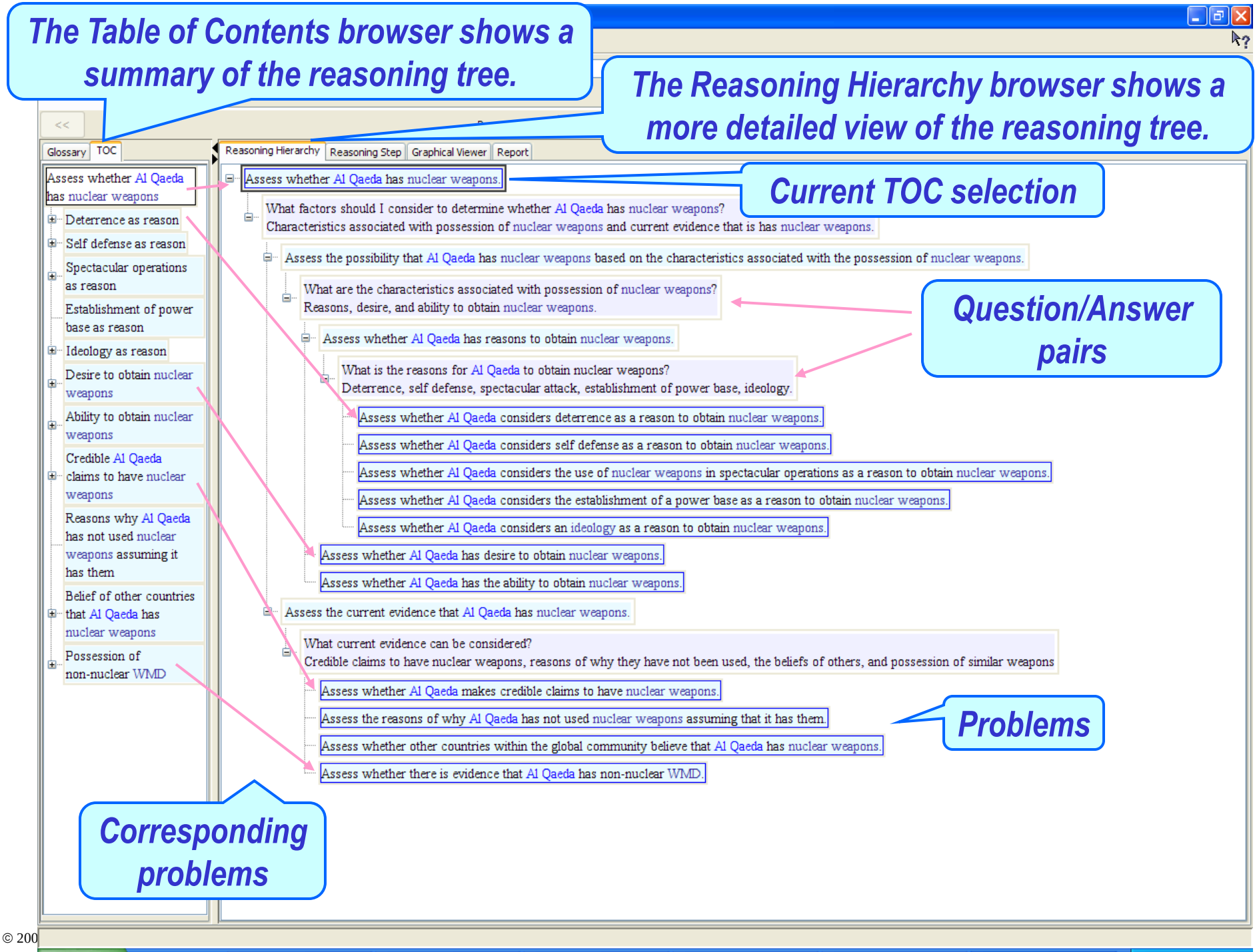
Mixed-Initiative Reasoner
Minimize or maximize pane
Minimize or maximize pane
Reasoning type: Decomposition
Reasoning mode: Modeling
Glossary
TOC
Assess whether Al Qaeda has nuclear weapons
Deterrence as reason
Self defense as reason
Spectacular operations as reason
Establishment of power base as reason
Ideology as reason
Desire to obtain nuclear weapons
Ability to obtain nuclear weapons
Credible Al Qaeda claims to have nuclear weapons
Reasons why Al Qaeda has not used nuclear weapons assuming it has them
Belief of other countries that Al Qaeda has nuclear weapons
Possession of non-nuclear WMD
Reasoning Hierarchy
Reasoning Step
Graphical Viewer
Report
Assess whether Al Qaeda has nuclear weapons.
What factors should I consider to determine whether Al Qaeda has nuclear weapons?
Characteristics associated with possession of nuclear weapons and current evidence that is has nuclear weapons.
Assess the possibility that Al Qaeda has nuclear weapons based on the characteristics associated with the possession of nuclear weapons.
What are the characteristics associated with possession of nuclear weapons?
Reasons, desire, and ability to obtain nuclear weapons.
Assess whether Al Qaeda has reasons to obtain nuclear weapons.
Assess whether Al Qaeda has desire to obtain nuclear weapons.
Assess whether Al Qaeda has the ability to obtain nuclear weapons.
Assess the current evidence that Al Qaeda has nuclear weapons.
What current evidence can be considered?
Credible claims to have nuclear weapons, reasons of why they have not been used, the beliefs of others, and possession of similar weapons
Assess whether Al Qaeda makes credible claims to have nuclear weapons.
Assess the reasons of why Al Qaeda has not used nuclear weapons assuming that it has them.
Assess whether other countries within the global community believe that Al Qaeda has nuclear weapons.
Assess whether there is evidence that Al Qaeda has non-nuclear WMD.
External Solutions
Assumption Assistant
Modeling
Evidence
Refinement
Search
Formalization
Composition Example Refinement
Modify Explanations
Correct Composition
Incorrect Composition
Refinement Wizards
Continue Learning
Correct SubTree Wizard
Analyze SubTree Wizard
Similar Case Wizard
Move to change pane size
The Table of Contents browser shows a summary of the reasoning tree.
The Reasoning Hierarchy browser shows a more detailed view of the reasoning tree.
Various assistants help with specific functions


The Table of Contents browser shows a summary of the reasoning tree.
The Reasoning Hierarchy browser shows a more detailed view of the reasoning tree.
Glossary
TOC
Reasoning Hierarchy
Reasoning Step
Graphical Viewer
Report
Assess whether Al Qaeda has nuclear weapons
Deterrence as reason
Self defense as reason
Spectacular operations as reason
Establishment of power base as reason
Ideology as reason
Desire to obtain nuclear weapons
Ability to obtain nuclear weapons
Credible Al Qaeda claims to have nuclear weapons
Reasons why Al Qaeda has not used nuclear weapons assuming it has them
Belief of other countries that Al Qaeda has nuclear weapons
Possession of non-nuclear WMD
Assess whether Al Qaeda has nuclear weapons.
Current TOC selection
What factors should I consider to determine whether Al Qaeda has nuclear weapons?
Characteristics associated with possession of nuclear weapons and current evidence that is has nuclear weapons.
Assess the possibility that Al Qaeda has nuclear weapons based on the characteristics associated with the possession of nuclear weapons.
What are the characteristics associated with possession of nuclear weapons?
Reasons, desire, and ability to obtain nuclear weapons.
Question/Answer pairs
Assess whether Al Qaeda has reasons to obtain nuclear weapons.
What is the reasons for Al Qaeda to obtain nuclear weapons?
Deterrence, self defense, spectacular attack, establishment of power base, ideology.
Assess whether Al Qaeda considers deterrence as a reason to obtain nuclear weapons.
Assess whether Al Qaeda considers self defense as a reason to obtain nuclear weapons.
Assess whether Al Qaeda considers the use of nuclear weapons in spectacular operations as a reason to obtain nuclear weapons.
Assess whether Al Qaeda considers the establishment of a power base as a reason to obtain nuclear weapons.
Assess whether Al Qaeda considers an ideology as a reason to obtain nuclear weapons.
Assess whether Al Qaeda has desire to obtain nuclear weapons.
Assess whether Al Qaeda has the ability to obtain nuclear weapons.
Assess the current evidence that Al Qaeda has nuclear weapons.
What current evidence can be considered?
Credible claims to have nuclear weapons, reasons of why they have not been used, the beliefs of others, and possession of similar weapons
Assess whether Al Qaeda makes credible claims to have nuclear weapons.
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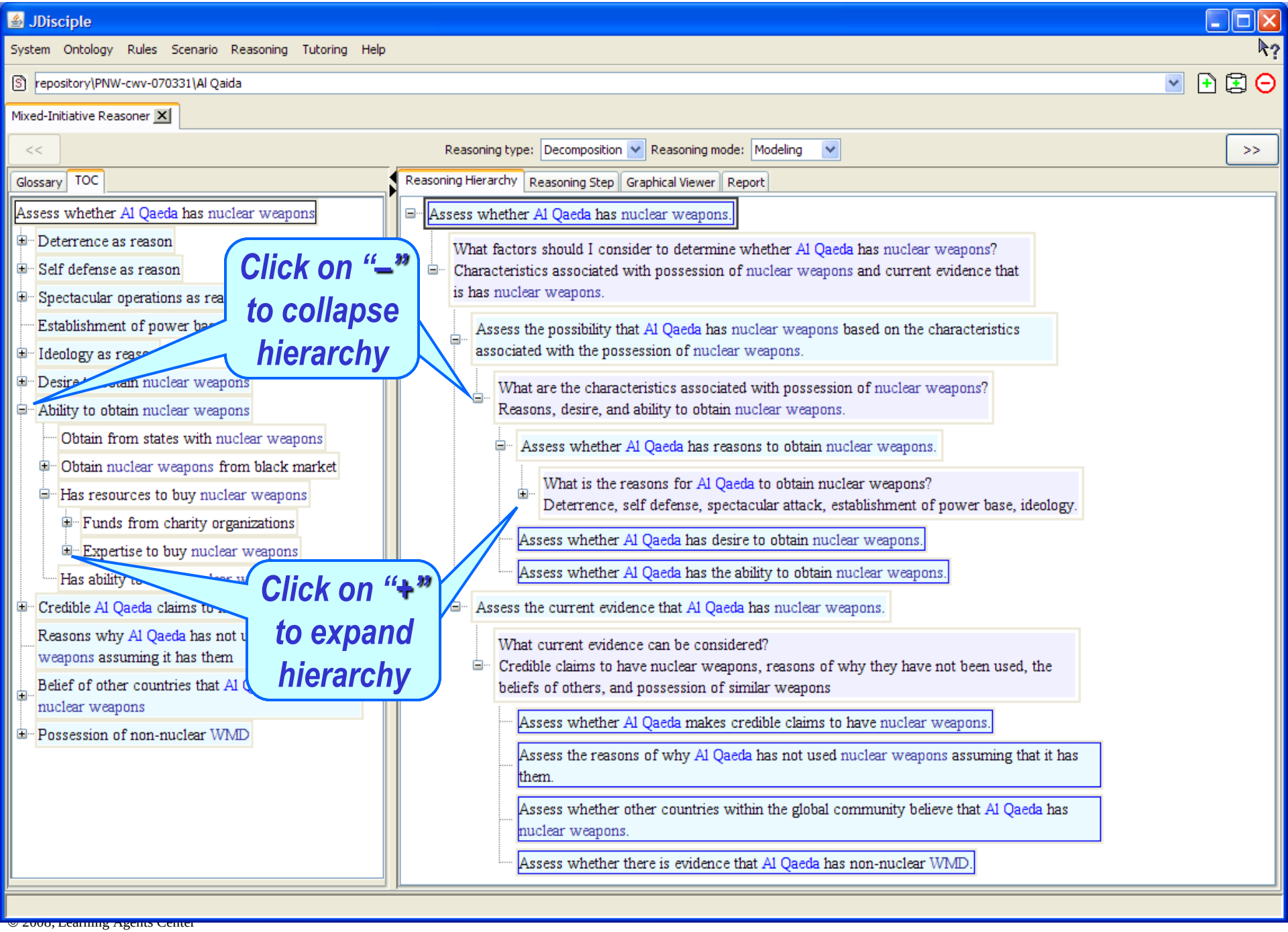
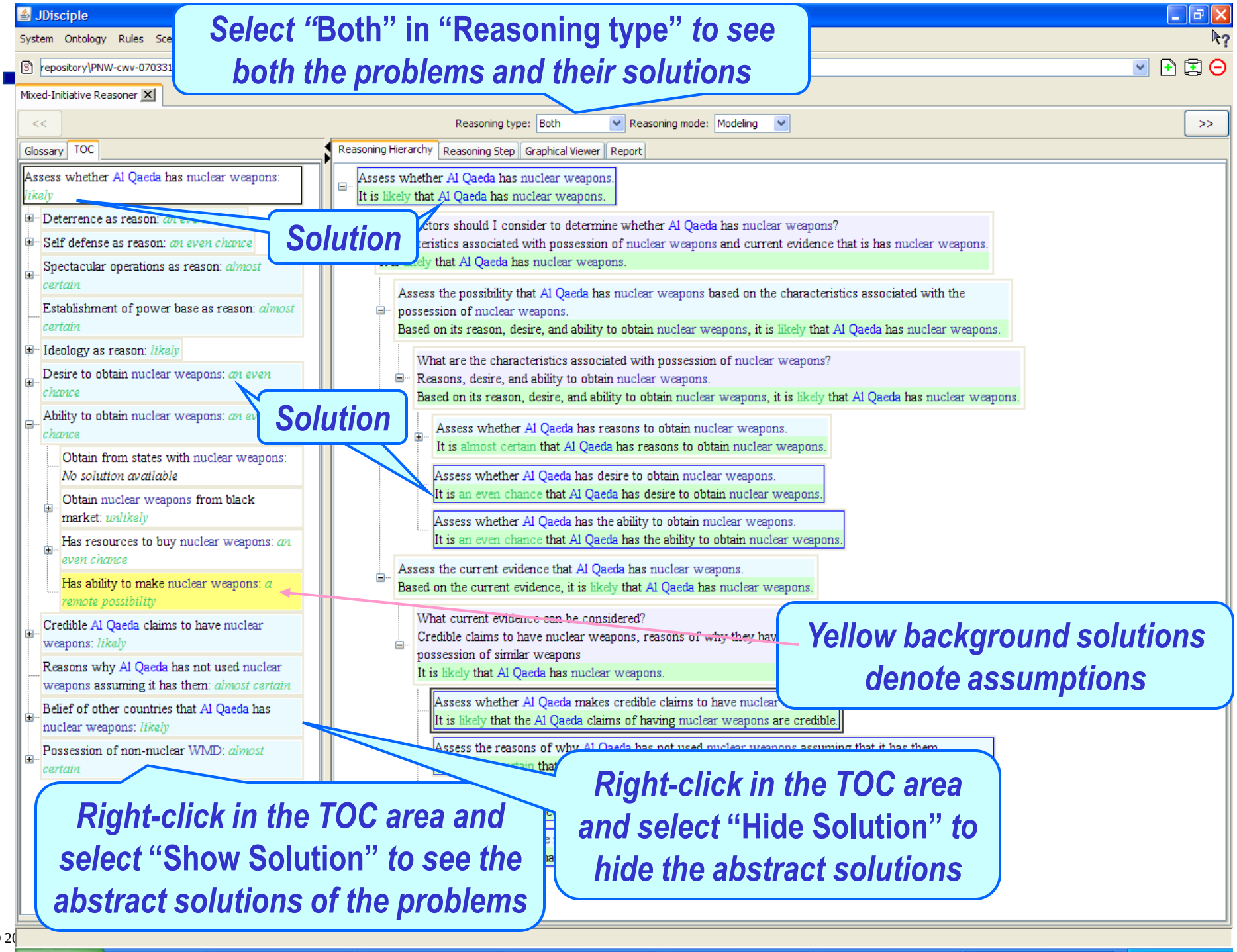
Assess whether other countries within the global community believe that Al Qaeda has nuclear weapons.
Assess whether there is evidence that Al Qaeda has non-nuclear WMD.
Problems
Corresponding problems




Select "Both" in "Reasoning type" to see both the problems and their solutions
JDisciple
System Ontology Rules Sce
repository\PNW-cwv-070331
Mixed-Initiative Reasoner
Reasoning type: Both
Reasoning mode: Modeling
Glossary TOC
Reasoning Hierarchy Reasoning Step Graphical Viewer Report
Assess whether Al Qaeda has nuclear weapons: likely
Deterrence as reason: an even
Self defense as reason: an even chance
Spectacular operations as reason: almost certain
Establishment of power base as reason: almost certain
Ideology as reason: likely
Desire to obtain nuclear weapons: an even chance
Ability to obtain nuclear weapons: an ev chance
Obtain from states with nuclear weapons: No solution available
Obtain nuclear weapons from black market: unlikely
Has resources to buy nuclear weapons: an even chance
Has ability to make nuclear weapons: a remote possibility
Credible Al Qaeda claims to have nuclear weapons: likely
Reasons why Al Qaeda has not used nuclear weapons assuming it has them: almost certain
Belief of other countries that Al Qaeda has nuclear weapons: likely
Possession of non-nuclear WMD: almost certain
Assess whether Al Qaeda has nuclear weapons.
It is likely that Al Qaeda has nuclear weapons.
ctors should I consider to determine whether Al Qaeda has nuclear weapons?
teristics associated with possession of nuclear weapons and current evidence that is has nuclear weapons.
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Assess the possibility that Al Qaeda has nuclear weapons based on the characteristics associated with the possession of nuclear weapons.
Based on its reason, desire, and ability to obtain nuclear weapons, it is likely that Al Qaeda has nuclear weapons.
What are the characteristics associated with possession of nuclear weapons?
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Based on its reason, desire, and ability to obtain nuclear weapons, it is likely that Al Qaeda has nuclear weapons.
Assess whether Al Qaeda has reasons to obtain nuclear weapons.
It is almost certain that Al Qaeda has reasons to obtain nuclear weapons.
Assess whether Al Qaeda has desire to obtain nuclear weapons.
It is an even chance that Al Qaeda has desire to obtain nuclear weapons.
Assess whether Al Qaeda has the ability to obtain nuclear weapons.
It is an even chance that Al Qaeda has the ability to obtain nuclear weapons.
Assess the current evidence that Al Qaeda has nuclear weapons.
Based on the current evidence, it is likely that Al Qaeda has nuclear weapons.
What current evidence can be considered?
Credible claims to have nuclear weapons, reasons of why they hav
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It is likely that Al Qaeda has nuclear weapons.
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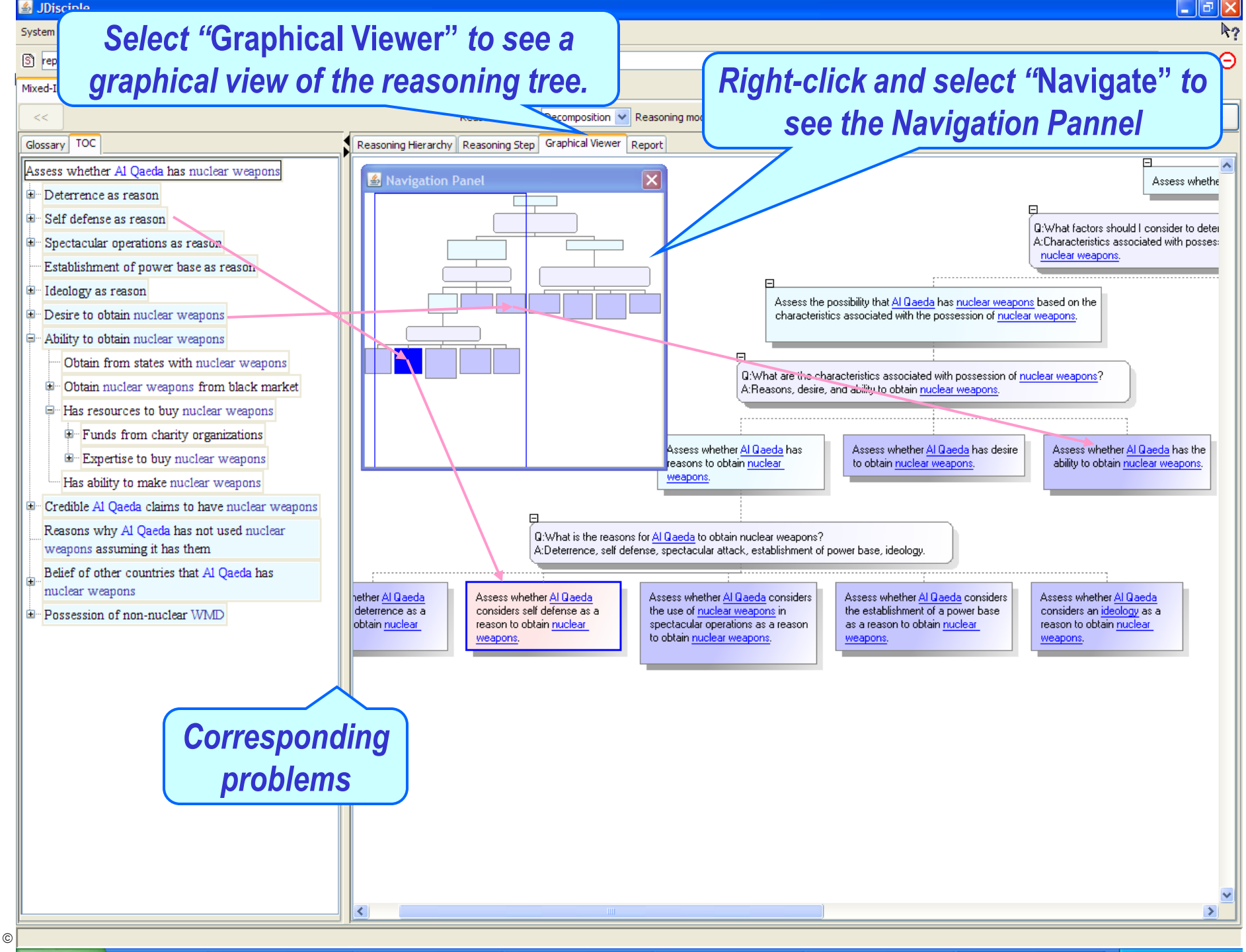
It is likely that the Al Qaeda claims of having nuclear weapons are credible.
Assess the reasons of why Al Qaeda has not used nuclear weapons assuming that it has them
Solution
Solution
Yellow background solutions denote assumptions
Right-click in the TOC area and select "Show Solution" to see the abstract solutions of the problems
Right-click in the TOC area and select "Hide Solution" to hide the abstract solutions


Select "Graphical Viewer" to see a graphical view of the reasoning tree.
Right-click and select "Navigate" to see the Navigation Pannel
Corresponding problems
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Reasoning Step
Graphical Viewer
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Navigation Panel
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Self defense as reason
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Ideology as reason
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Ability to obtain nuclear weapons
Obtain from states with nuclear weapons
Obtain nuclear weapons from black market
Has resources to buy nuclear weapons
Funds from charity organizations
Expertise to buy nuclear weapons
Has ability to make nuclear weapons
Credible Al Qaeda claims to have nuclear weapons
Reasons why Al Qaeda has not used nuclear weapons assuming it has them
Belief of other countries that Al Qaeda has nuclear weapons
Possession of non-nuclear WMD
Q:What factors should I consider to deter
A:Characteristics associated with posses
nuclear weapons.
Assess the possibility that Al Qaeda has nuclear weapons based on the characteristics associated with the possession of nuclear weapons.
Q:What are the characteristics associated with possession of nuclear weapons?
A:Reasons, desire, and ability to obtain nuclear weapons.
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Assess whether Al Qaeda has the ability to obtain nuclear weapons.
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A:Deterrence, self defense, spectacular attack, establishment of power base, ideology.
Assess whether Al Qaeda considers self defense as a reason to obtain nuclear weapons.
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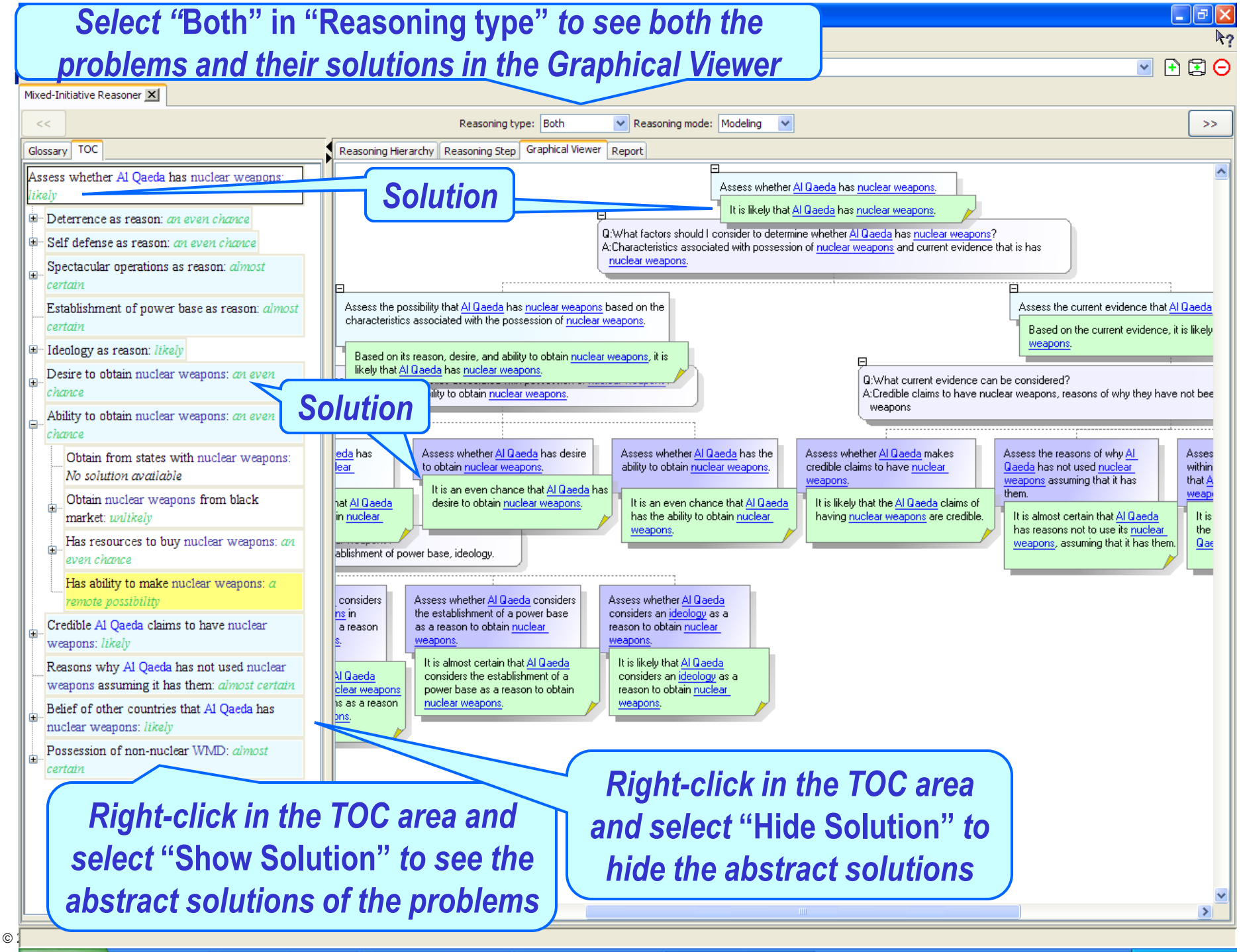
Assess whether Al Qaeda considers an ideology as a reason to obtain nuclear weapons.


Select "Both" in "Reasoning type" to see both the problems and their solutions in the Graphical Viewer
Mixed-Initiative Reasoner
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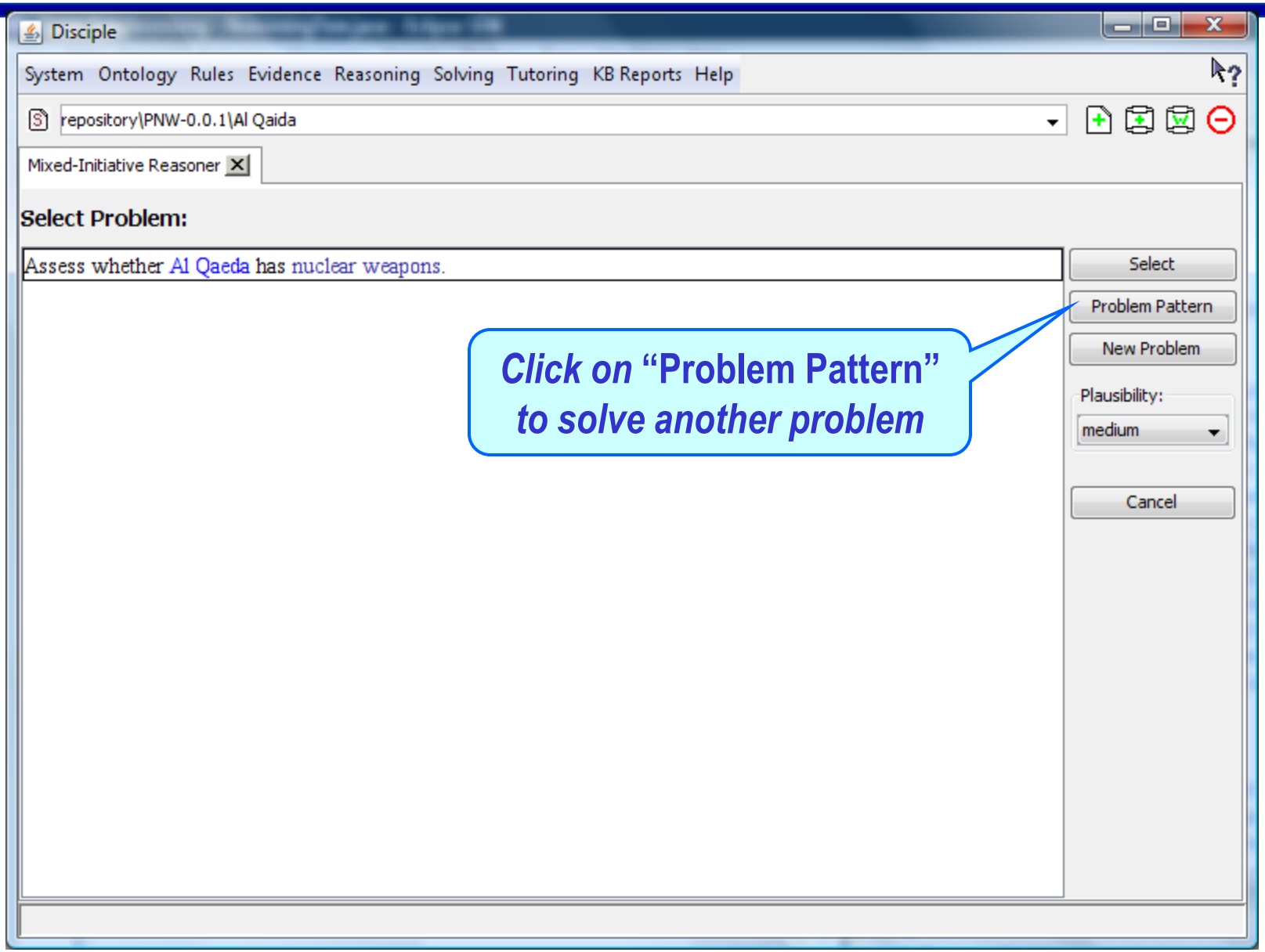
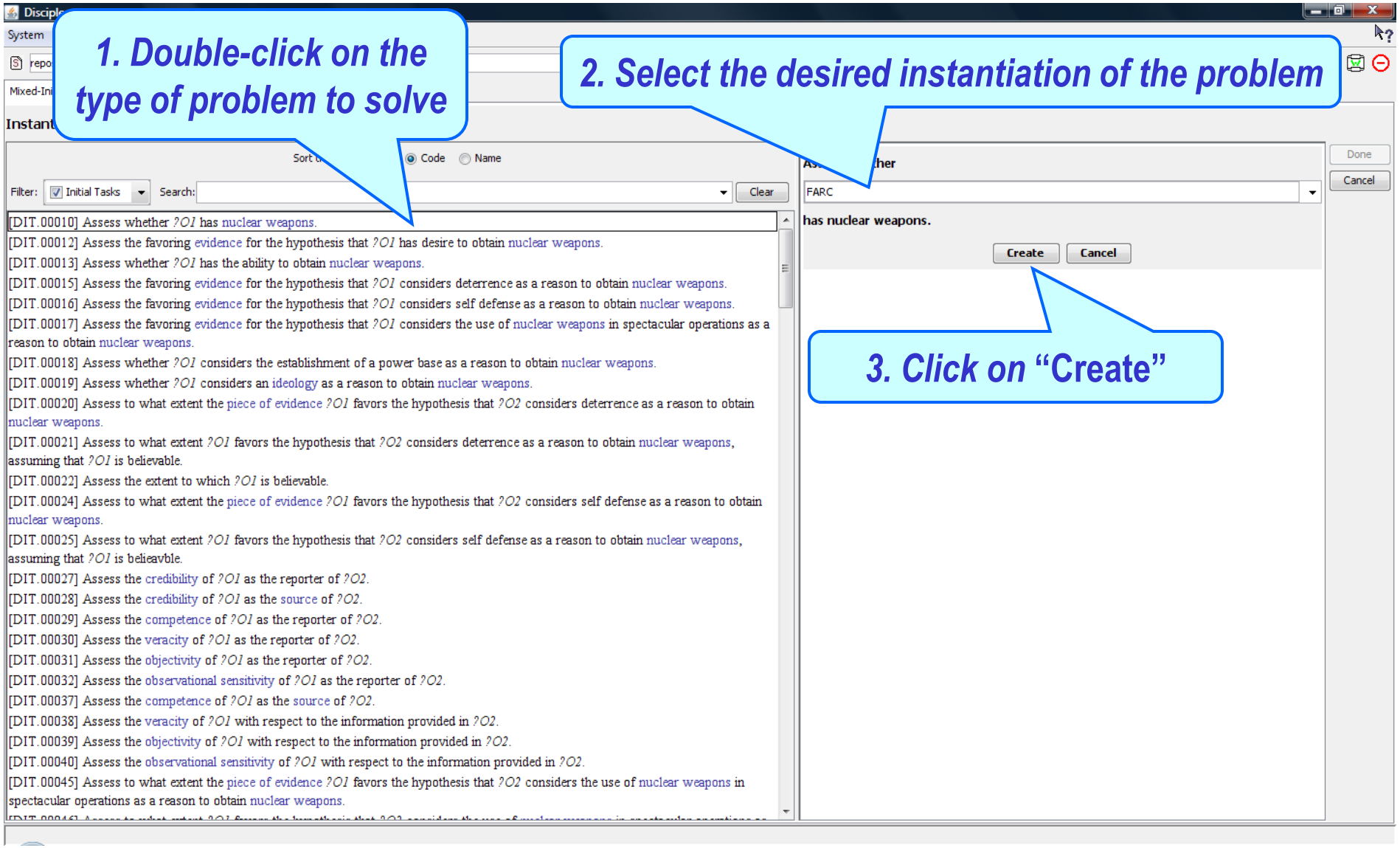
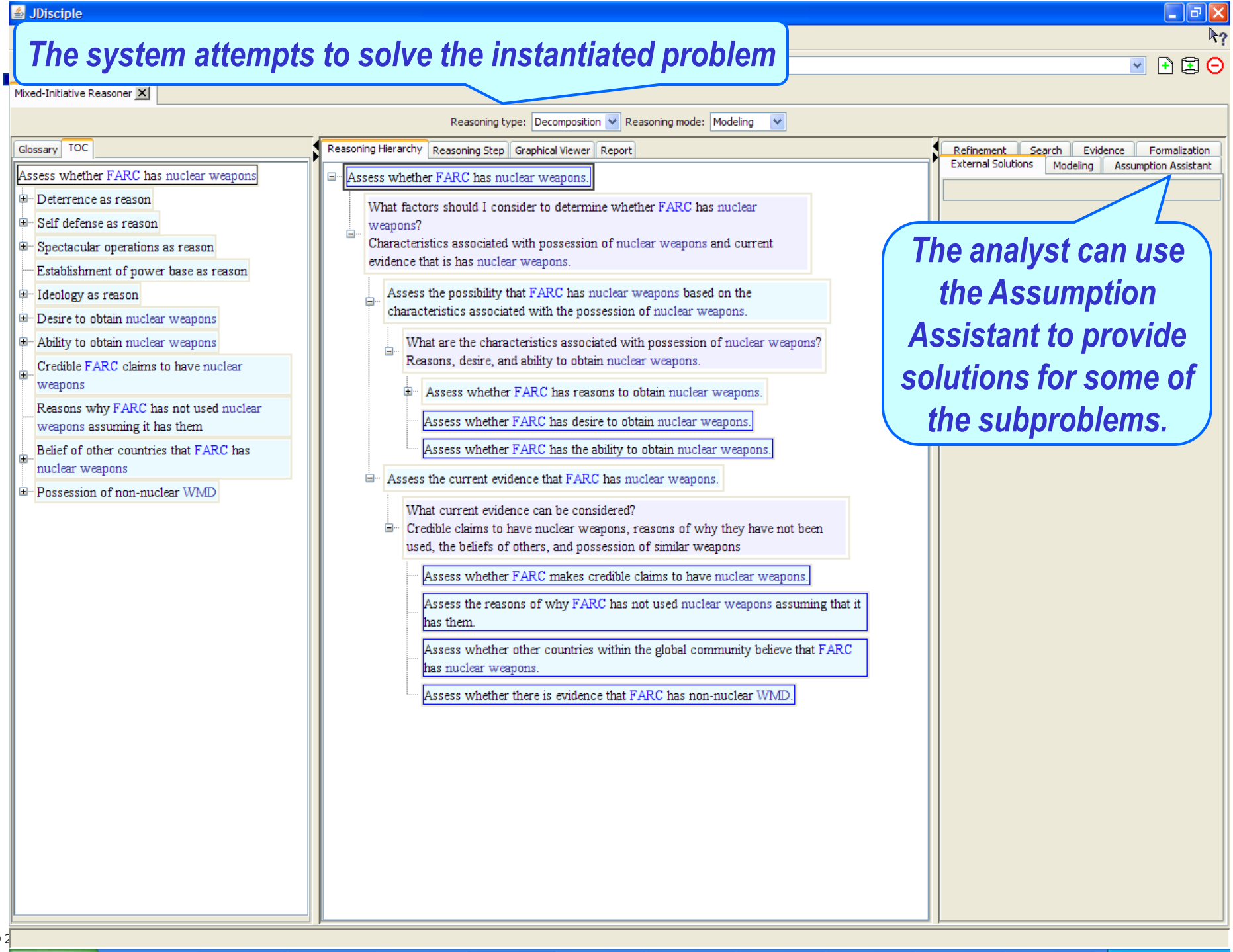
Credible Al Qaeda claims to have nuclear weapons: likely
Reasons why Al Qaeda has not used nuclear weapons assuming it has them: almost certain
Belief of other countries that Al Qaeda has nuclear weapons: likely
Possession of non-nuclear WMD: almost certain
Solution
Assess whether Al Qaeda has nuclear weapons.
It is likely that Al Qaeda has nuclear weapons.
Q:What factors should I consider to determine whether Al Qaeda has nuclear weapons?
A:Characteristics associated with possession of nuclear weapons and current evidence that is has nuclear weapons.
Assess the possibility that Al Qaeda has nuclear weapons based on the characteristics associated with the possession of nuclear weapons.
Based on its reason, desire, and ability to obtain nuclear weapons, it is likely that Al Qaeda has nuclear weapons.
Assess the current evidence that Al Qaeda
Based on the current evidence, it is likely
weapons.
Q:What current evidence can be considered?
A:Credible claims to have nuclear weapons, reasons of why they have not bee
weapons
Solution
Assess whether Al Qaeda has desire to obtain nuclear weapons.
It is an even chance that Al Qaeda has desire to obtain nuclear weapons.
Assess whether Al Qaeda has the ability to obtain nuclear weapons.
It is an even chance that Al Qaeda has the ability to obtain nuclear weapons.
Assess whether Al Qaeda makes credible claims to have nuclear weapons.
It is likely that the Al Qaeda claims of having nuclear weapons are credible.
Assess the reasons of why Al Qaeda has not used nuclear weapons assuming that it has them.
It is almost certain that Al Qaeda has reasons not to use its nuclear weapons, assuming that it has them.
Assess whether Al Qaeda considers the establishment of a power base as a reason to obtain nuclear weapons.
It is almost certain that Al Qaeda considers the establishment of a power base as a reason to obtain nuclear weapons.
Assess whether Al Qaeda considers an ideology as a reason to obtain nuclear weapons.
It is likely that Al Qaeda considers an ideology as a reason to obtain nuclear weapons.
Right-click in the TOC area and select "Show Solution" to see the abstract solutions of the problems
Right-click in the TOC area and select "Hide Solution" to hide the abstract solutions





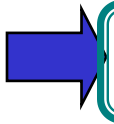

JDisciple
The system attempts to solve the instantiated problem
Mixed-Initiative Reasoner
Reasoning type: Decomposition
Reasoning mode: Modeling
Glossary
TOC
Assess whether FARC has nuclear weapons
Deterrence as reason
Self defense as reason
Spectacular operations as reason
Establishment of power base as reason
Ideology as reason
Desire to obtain nuclear weapons
Ability to obtain nuclear weapons
Credible FARC claims to have nuclear weapons
Reasons why FARC has not used nuclear weapons assuming it has them
Belief of other countries that FARC has nuclear weapons
Possession of non-nuclear WMD
Reasoning Hierarchy
Reasoning Step
Graphical Viewer
Report
Assess whether FARC has nuclear weapons.
What factors should I consider to determine whether FARC has nuclear weapons?
Characteristics associated with possession of nuclear weapons and current evidence that is has nuclear weapons.
Assess the possibility that FARC has nuclear weapons based on the characteristics associated with the possession of nuclear weapons.
What are the characteristics associated with possession of nuclear weapons?
Reasons, desire, and ability to obtain nuclear weapons.
Assess whether FARC has reasons to obtain nuclear weapons.
Assess whether FARC has desire to obtain nuclear weapons.
Assess whether FARC has the ability to obtain nuclear weapons.
Assess the current evidence that FARC has nuclear weapons.
What current evidence can be considered?
Credible claims to have nuclear weapons, reasons of why they have not been used, the beliefs of others, and possession of similar weapons
Assess whether FARC makes credible claims to have nuclear weapons.
Assess the reasons of why FARC has not used nuclear weapons assuming that it has them.
Assess whether other countries within the global community believe that FARC has nuclear weapons.
Assess whether there is evidence that FARC has non-nuclear WMD.
Refinement
Search
Evidence
Formalization
External Solutions
Modeling
Assumption Assistant
The analyst can use the Assumption Assistant to provide solutions for some of the subproblems.

Overview

Types of Problems for Expert Systems

General Problem Solving Paradigms

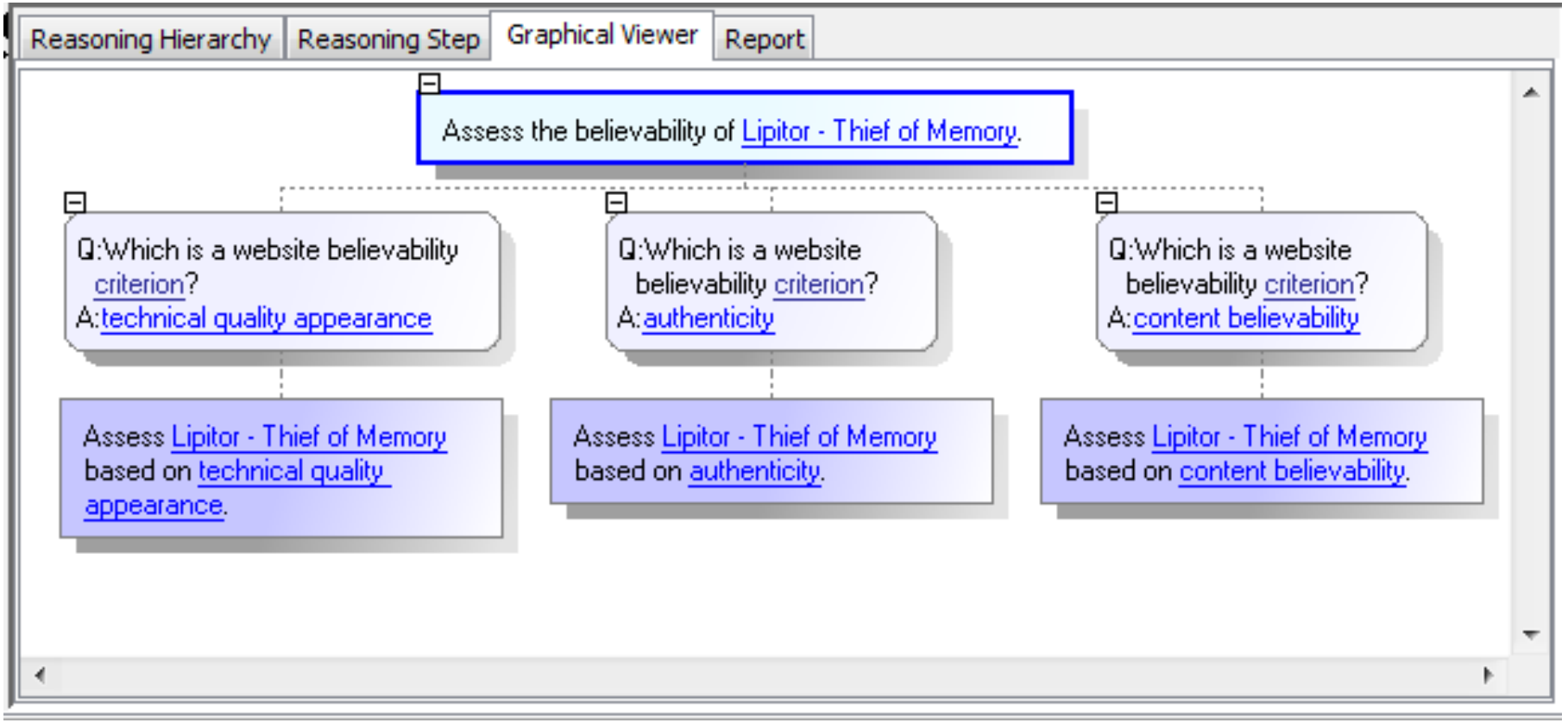
Hands on Disciple-LTA: Intelligence Analysis



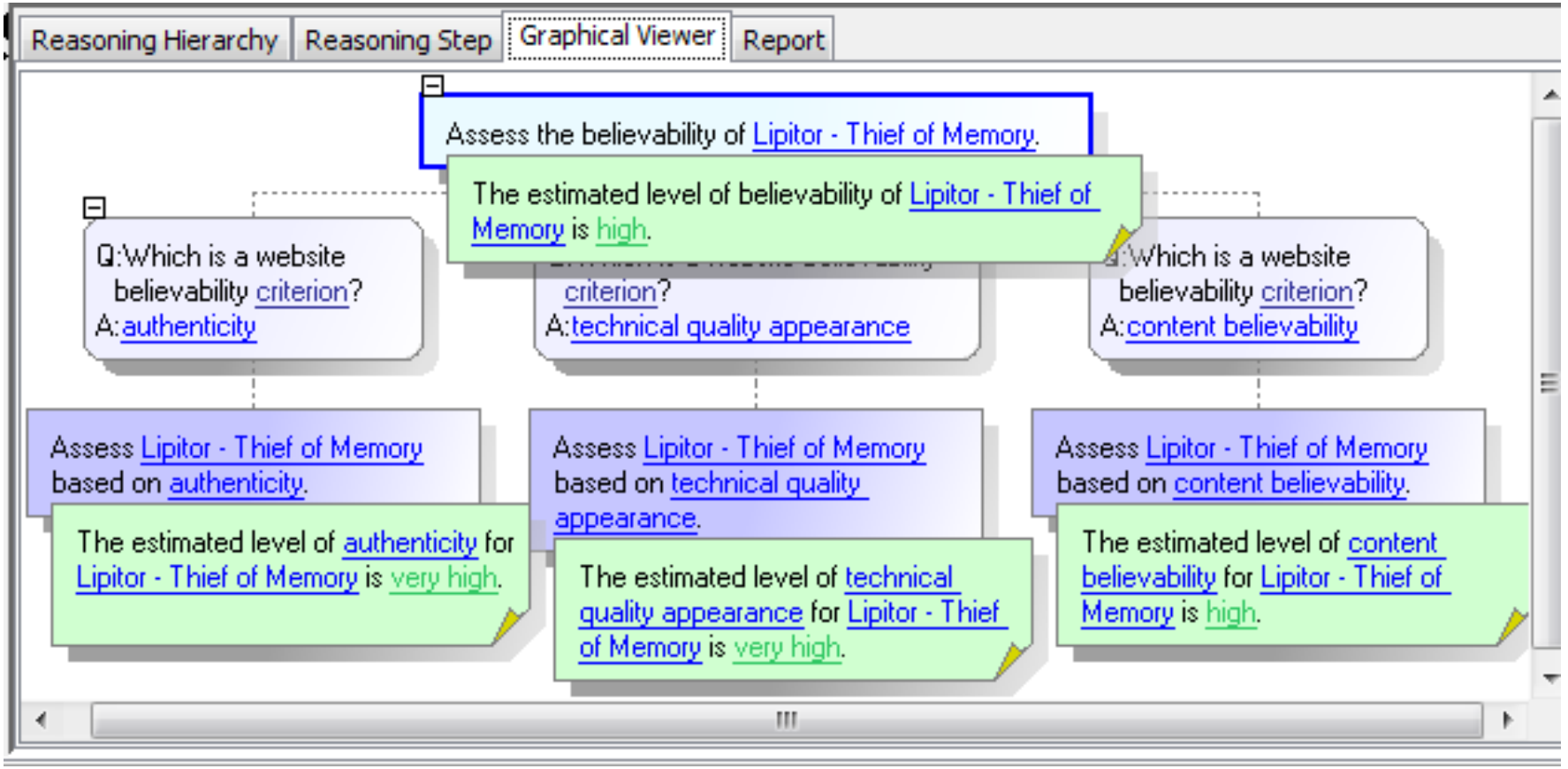
Website Believability as Expertise Problem

Reading

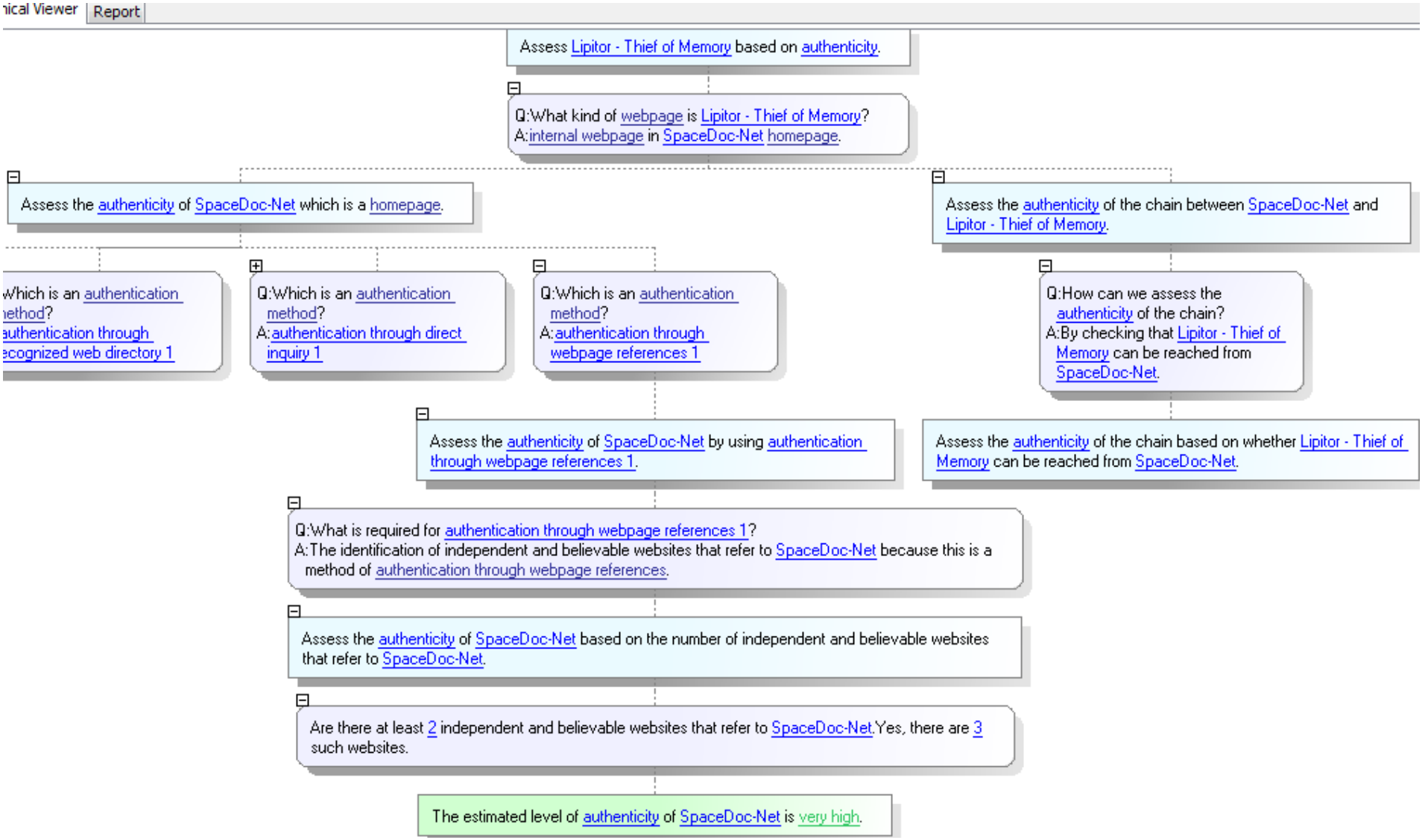
Top-level Reduction: Believability of Webpage



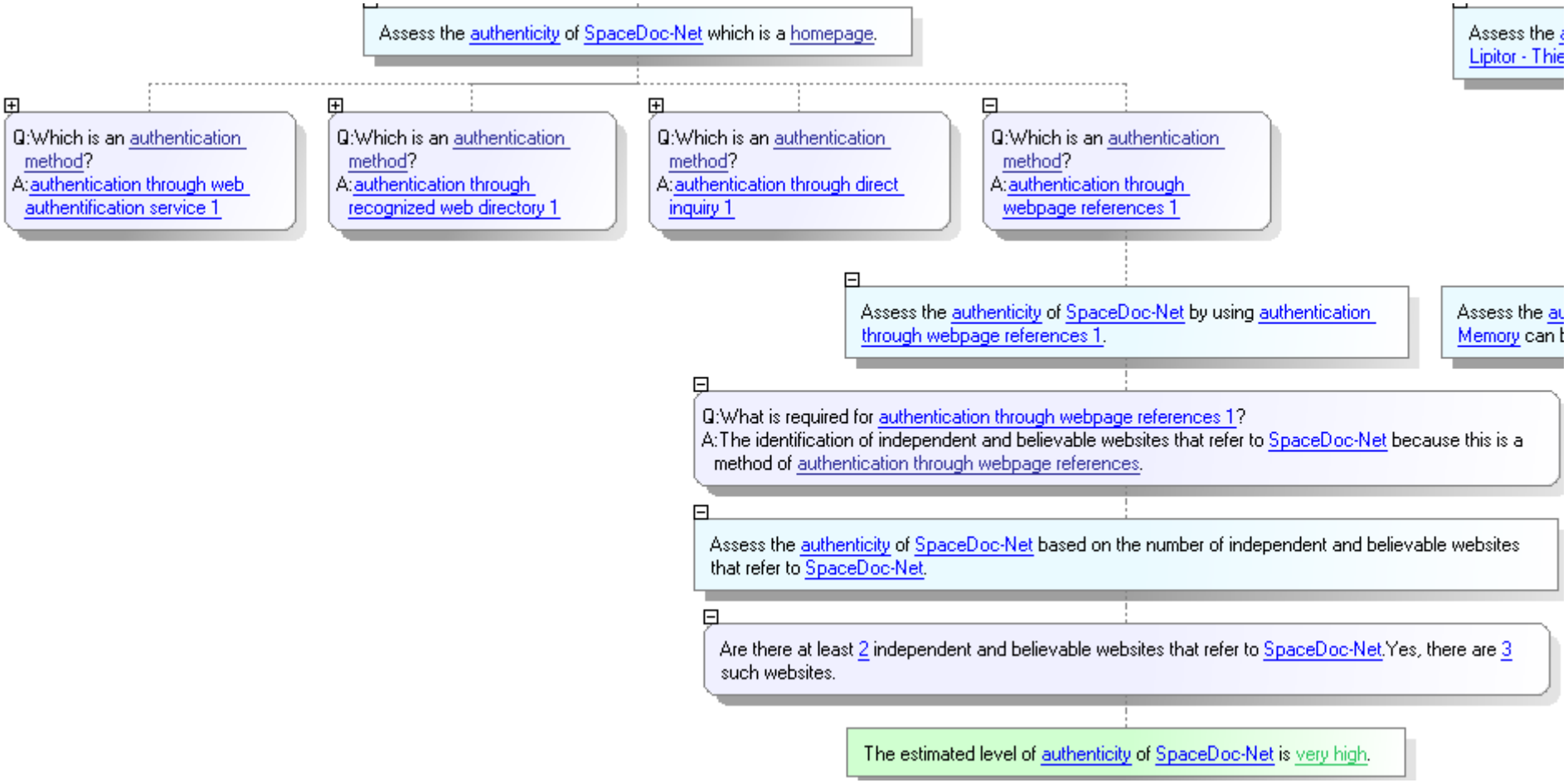
Top-level Synthesis



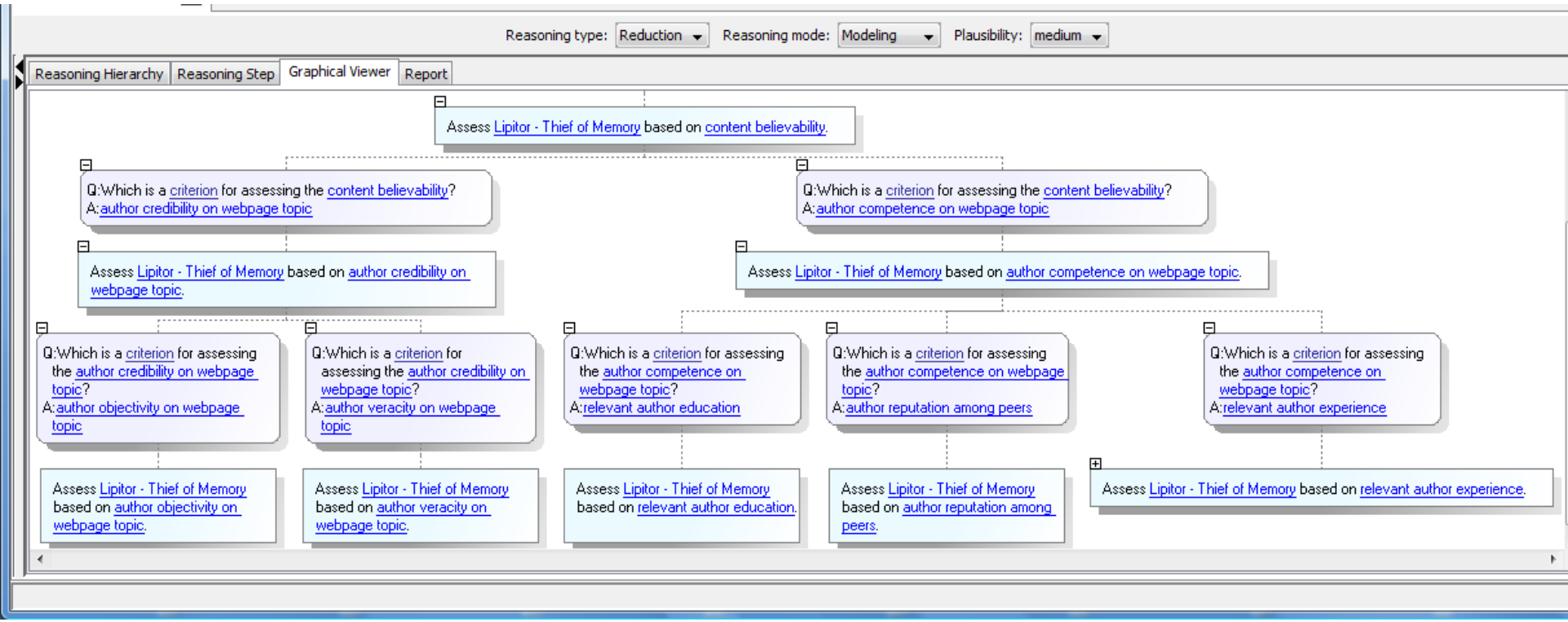
Webpage Authenticity: Reduction



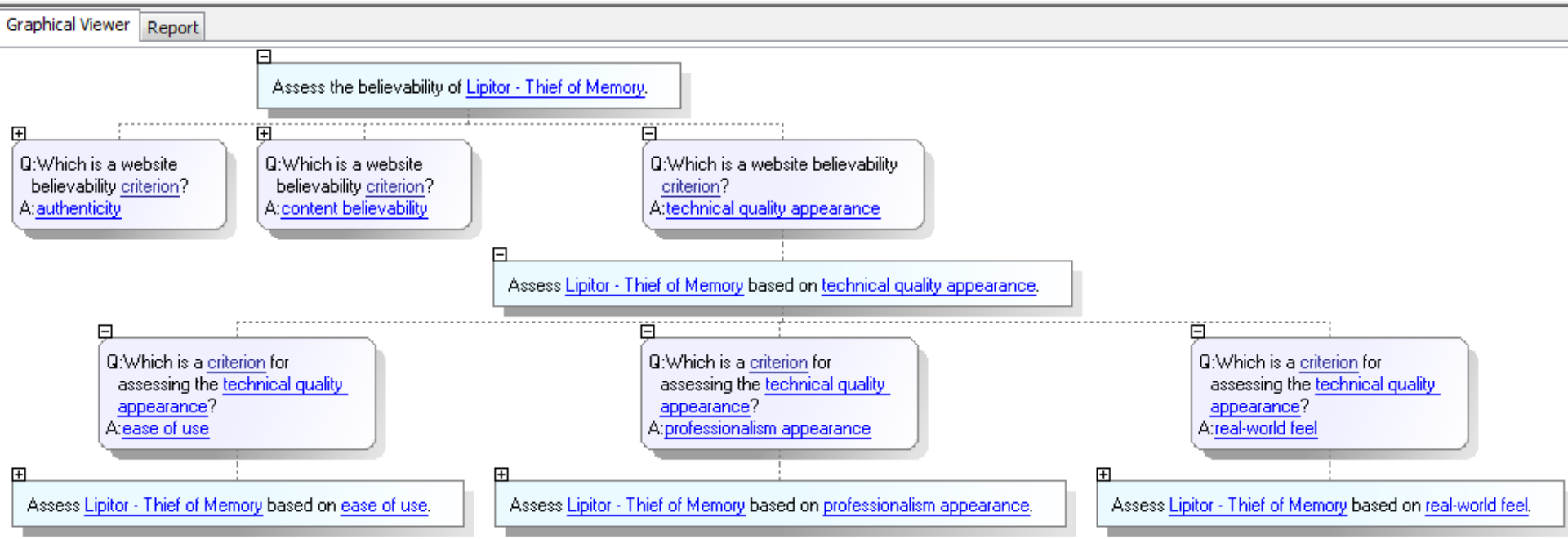
Authentication Methods



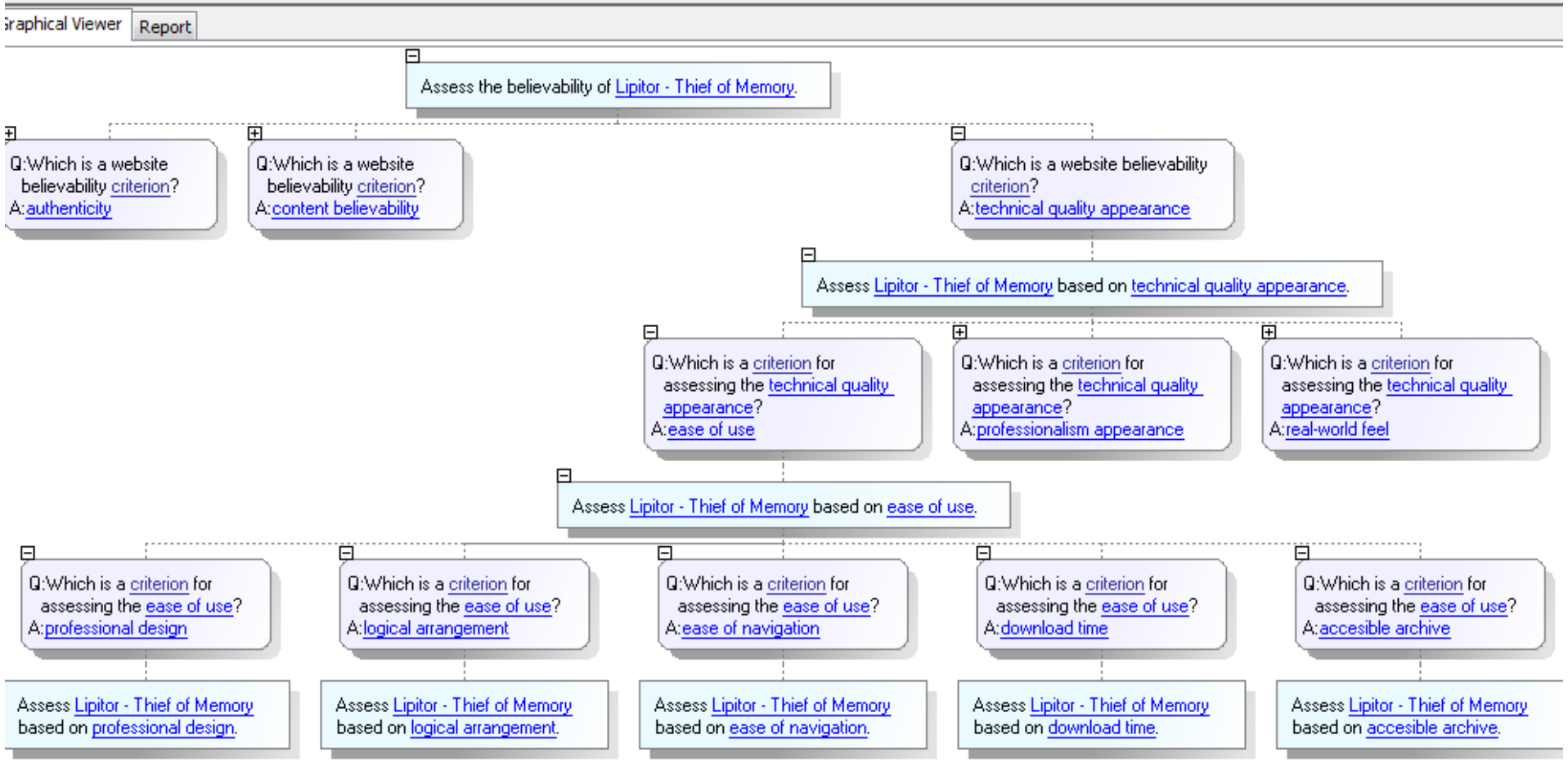
Content Believability: Reduction



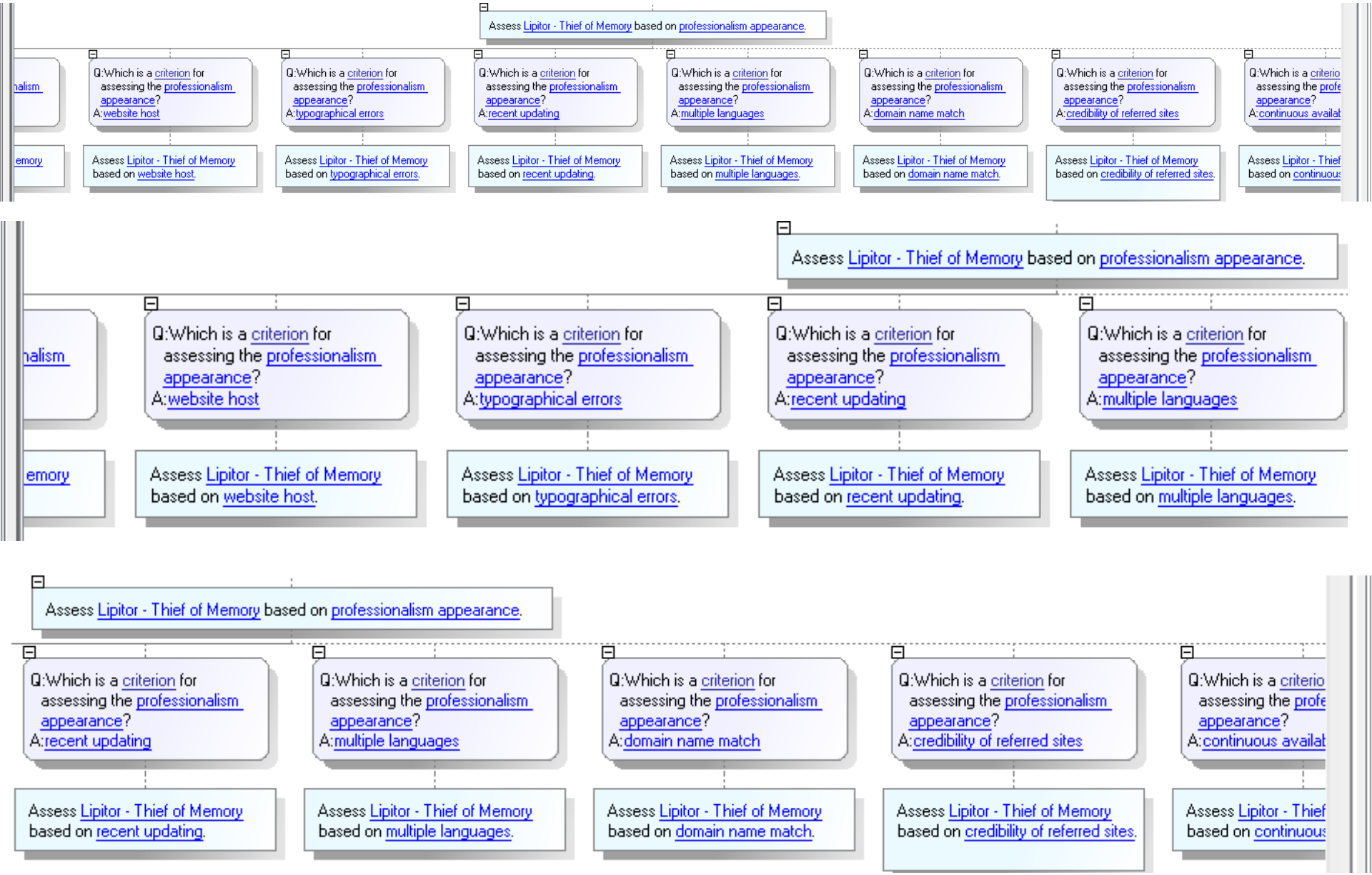
Technical Quality Appearance: Reduction



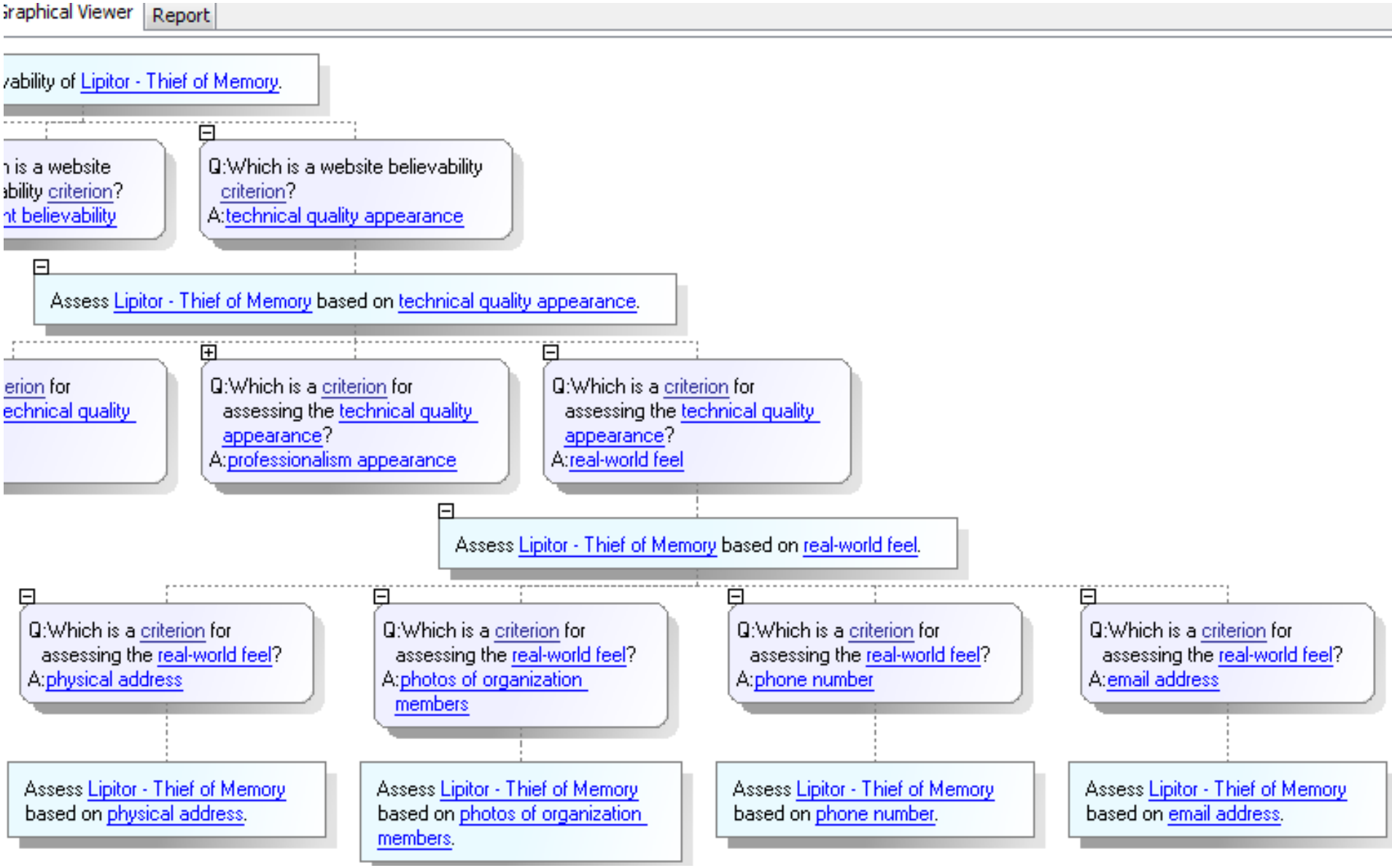
Ease of Use: Reduction



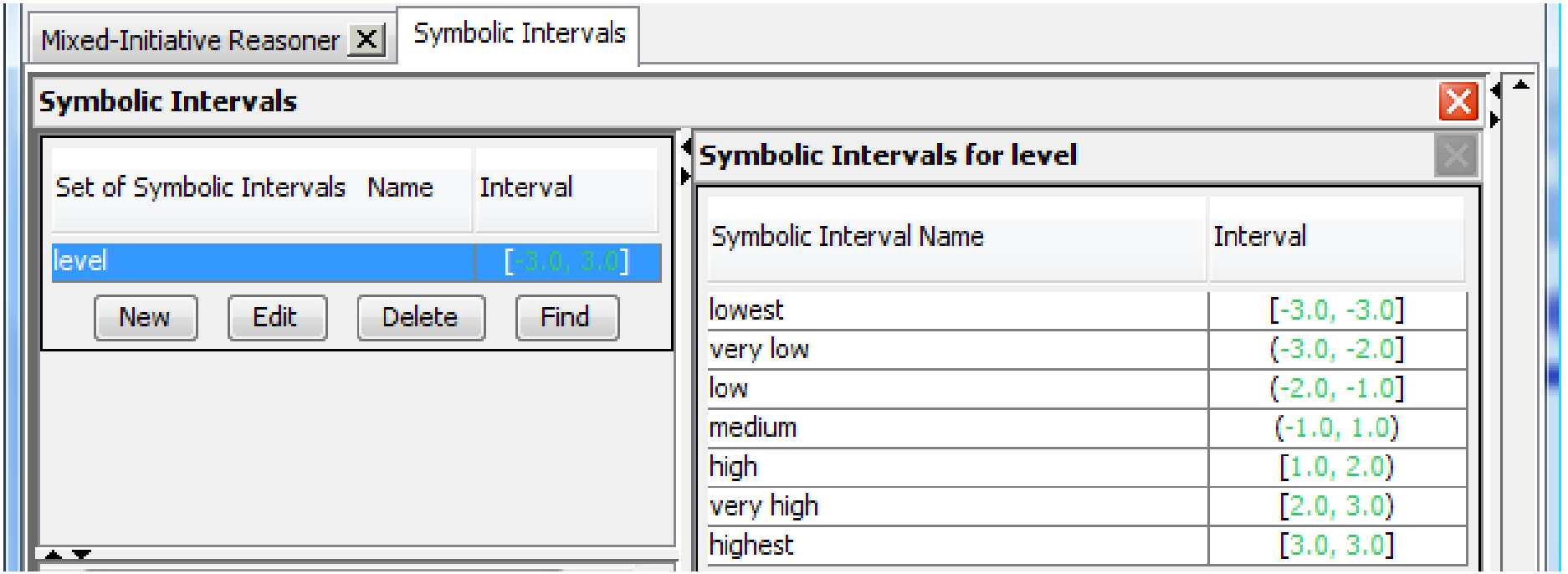
Professionalism Appearance: Reduction



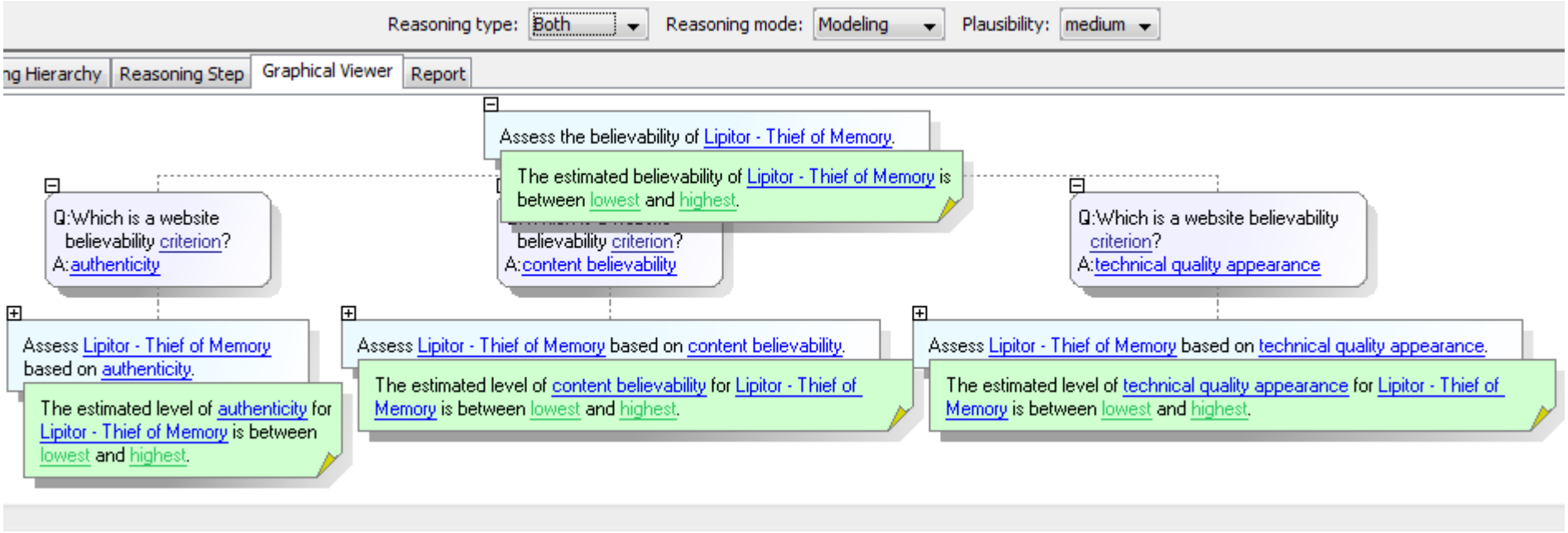
Real-world Feel: Reduction

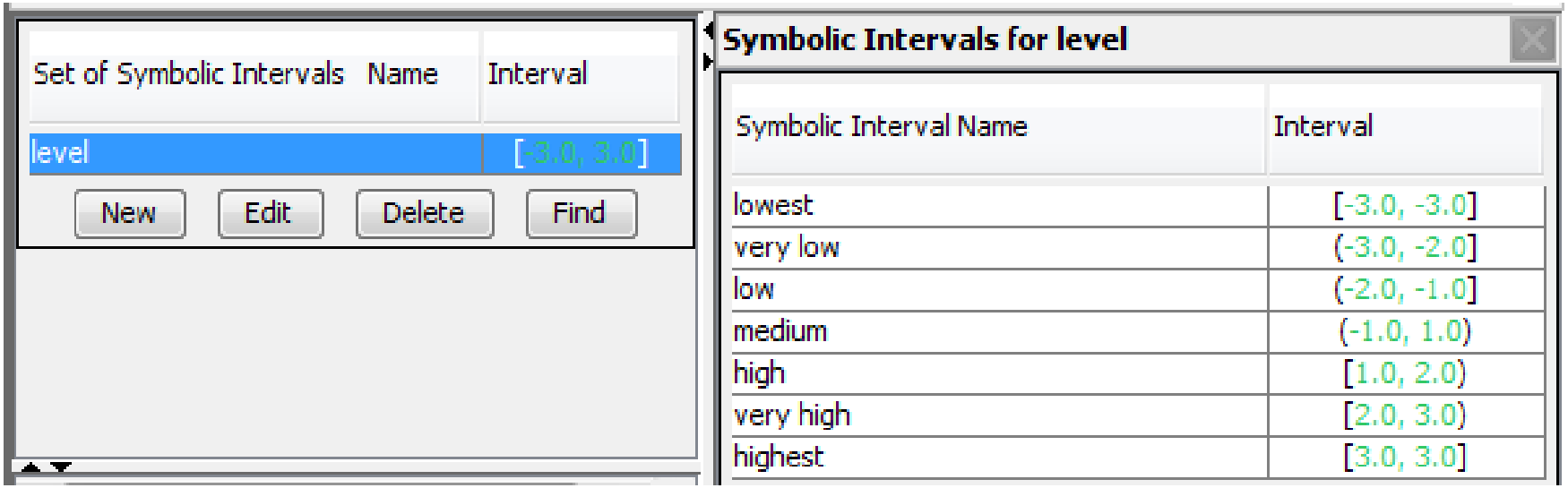


Reasoning with Incomplete Information



Top-level Synthesis with Incomplete Information





Reading

Tecuci G., Lecture Notes on Knowledge-Based Reasoning Part I, 2008 (required).

G.Tecuci, M. Boicu, D. Marcu, V. Le, C. Boicu, Disciple-LTA: Learning, Tutoring and Analytic Assistance, *Journal of Intelligence Community Research and Development, July 2008.* (required).
http://lac.gmu.edu/publications/2008/Disciple-LTA08.pdf