



CS 681 Fall 2008
Designing Expert Systems

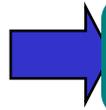
Knowledge-Based Reasoning: Part IV

Reasoning Mechanisms and Sample Systems

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Overview



Knowledge Base Organization

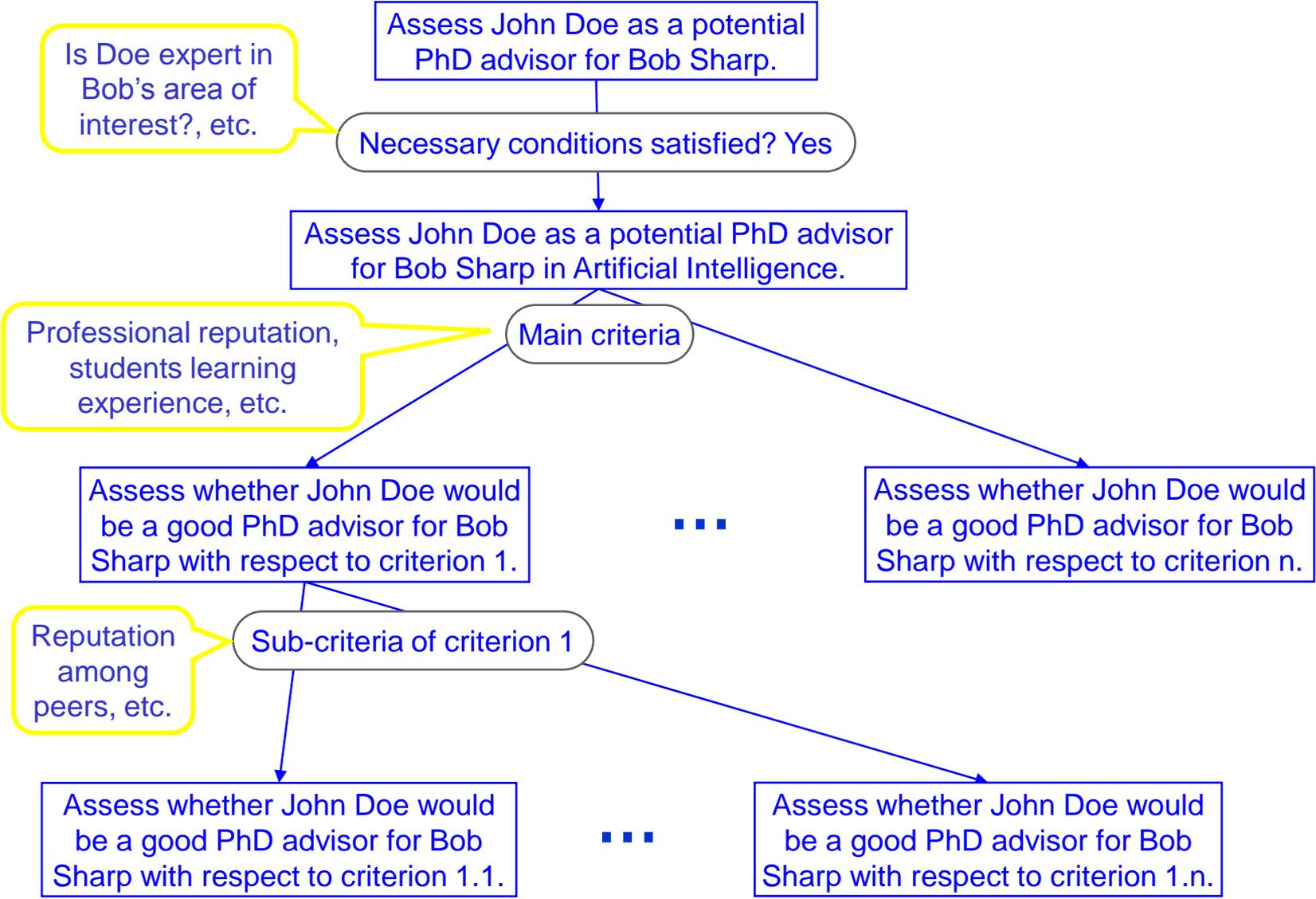
Reasoning Mechanisms

Disciple-COA: Critiquing as Expertise Problem

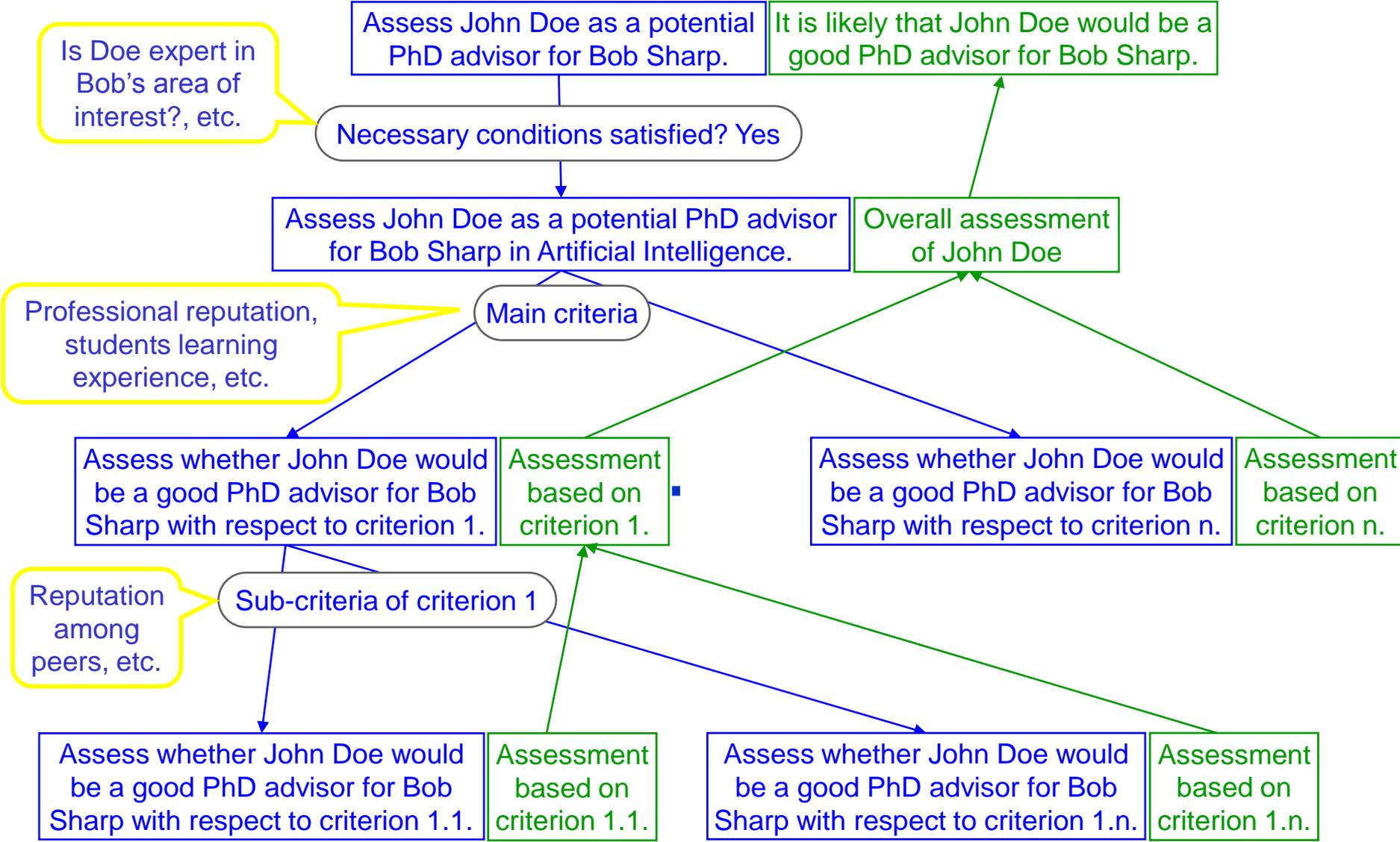
Disciple-WA: Workaround as Expertise Problem

Reading

PhD Advisor Assessment: Overall Reduction Logic



PhD Advisor Assessment: Overall Reduction Logic



Criteria and Sub-criteria

Necessary conditions

Professional reputation

Personality and compatibility
with student

Students' learning experience

Responsiveness to students

Support for students

Quality of student results

1. What is the reputation of the director within the professional community at large?
11. How expert is the director in your areas of interest?
14. Does the director have a research group, or merely a string of individual students?
15. Is the director's research work funded?
24. What is the quality of the dissertation produced with this director?

Criteria and Sub-criteria

Necessary conditions

Professional reputation

Personality and compatibility
with student

Students' learning experience

Responsiveness to students

Support for students

Quality of student results

- 12. Does the director publish with students?
- 14. Does the director have a research group, or merely a string of individual students?
- 19. Do the director's students go to conferences?
- 20. Do the director's students make presentations of their work at conferences?
- 24. What is the quality of the dissertation produced with this director?

Problem Reduction based Question-Answering

General problem solving paradigm:

- natural for the human user;
- appropriate for the automated agent.

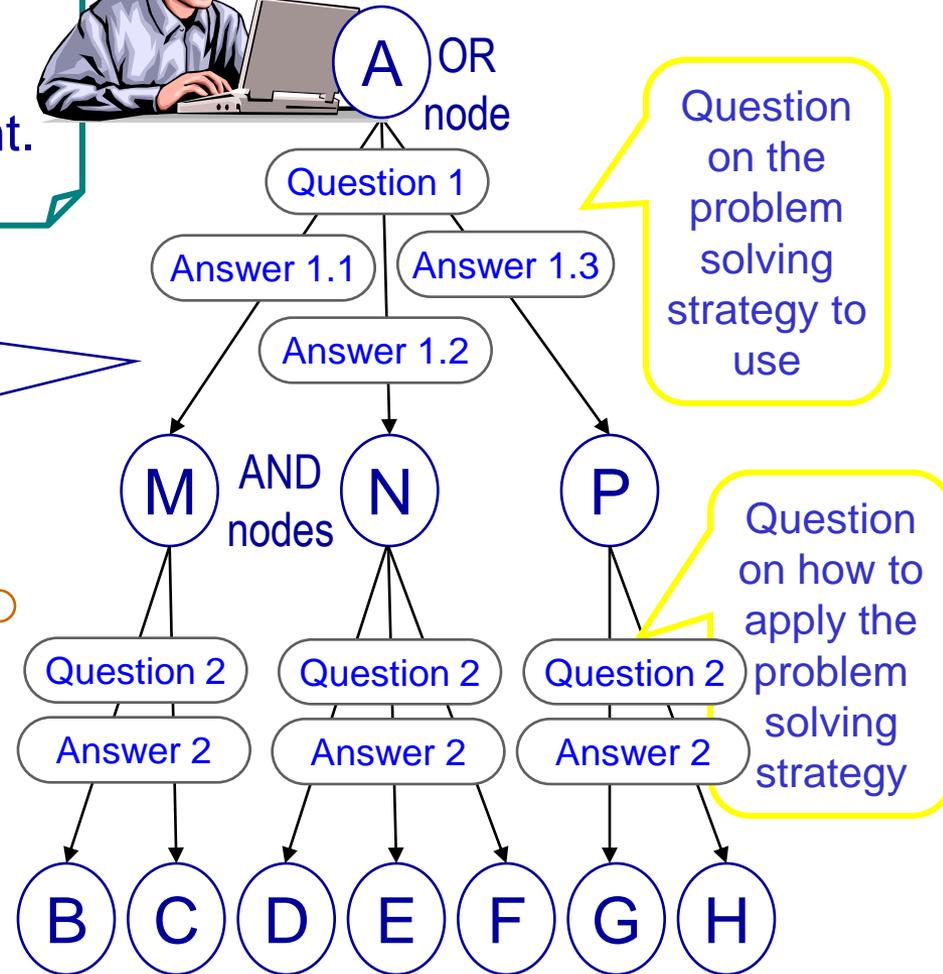


The reductions and synthesis operations are guided by introspective questions and answers.

"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

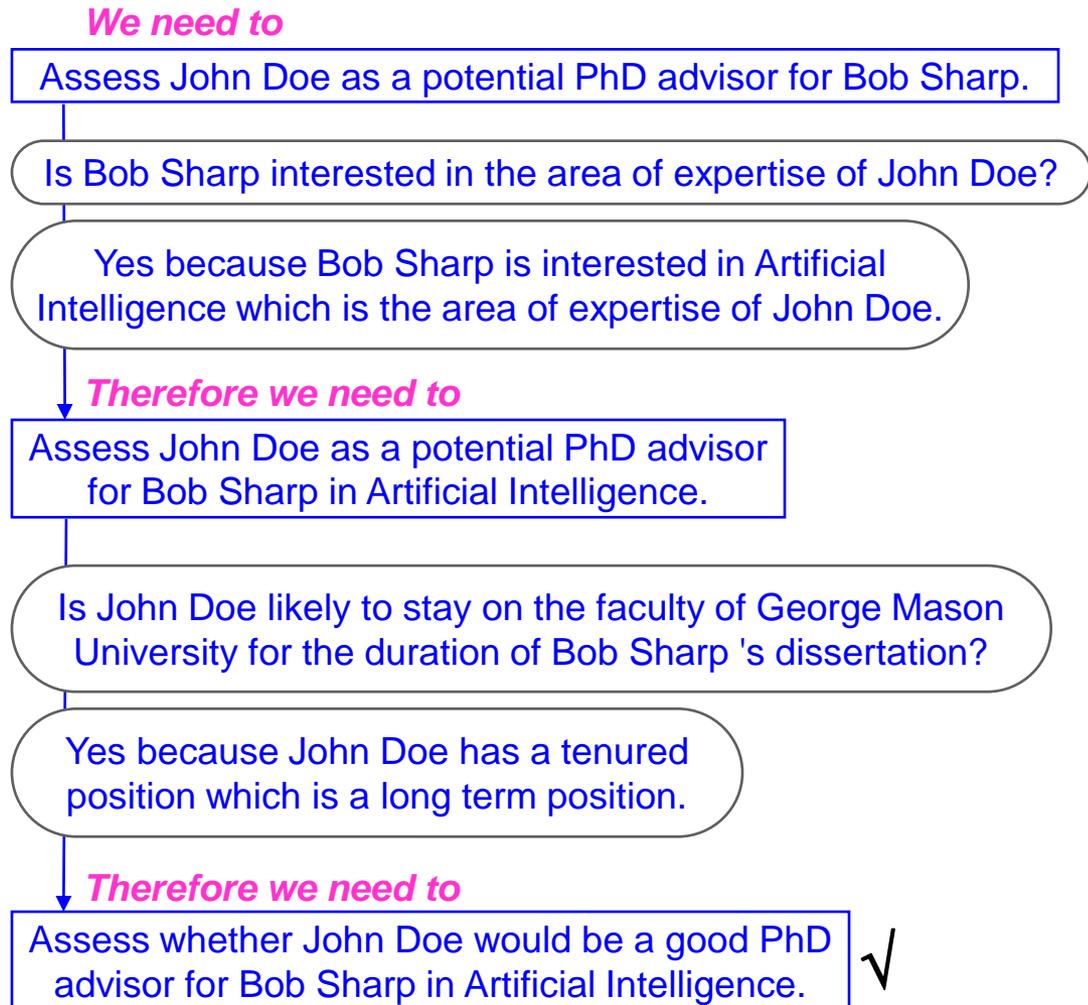


Question on the problem solving strategy to use

Question on how to apply the problem solving strategy

Detailed Reduction Logic

Notice the detailed justification of the answers: "Yes, because ..."



Problem Reduction

Necessary conditions satisfied

Detailed Reduction Logic

We need to

Assess whether John Doe would be a good PhD advisor for Bob Sharp in Artificial Intelligence.

Which is a PhD advisor quality criterion?

professional reputation

Therefore we need to

Assess whether John Doe would be a good PhD advisor for Bob Sharp with respect to professional reputation.

Which is a criterion for assessing professional reputation?

reputation among peers

Therefore we need to

Assess whether John Doe would be a good PhD advisor for Bob Sharp with respect to reputation among peers. ✓

research funding
...

students learning experience
...

Problem Reduction

Detailed Reduction Logic

We need to

Assess whether John Doe would be a good PhD advisor for Bob Sharp with respect to reputation among peers.

Which is a criterion for assessing reputation among peers?

research contributions

Therefore we need to

Assess whether John Doe would be a good PhD advisor for Bob Sharp with respect to research contributions. ✓

research publications

...

research memberships

...



Detailed Reduction Logic

We need to

Assess whether John Doe would be a good PhD advisor for Bob Sharp with respect to research contributions.

Which is a criterion for assessing research contributions?

citations in publications

Therefore we need to

Assess how cited John Doe is.

What publication cites John Doe?

Rice 2007 because it cites Doe 2000 which is authored by John Doe.

Therefore we conclude that

John Doe is cited in Rice 2007.

...

Knox 2003 because it cites Doe 2001 which is authored by John Doe.

Therefore we conclude that

John Doe is cited in Knox 2003.

readings in courses

Therefore we need to

Assess how many courses use publications by John Doe as readings.

Problem Reduction

Detailed Reduction and Synthesis Logic

We need to

Assess whether John Doe would be a good PhD advisor for Bob Sharp with respect to research contributions.

Which is a criterion for assessing research contributions?

citations in publications

Therefore we need to

Assess how cited John Doe is.

John Doe is cited in 250 publications.

What publication cites John Doe?

Rice 2007 because it cites ...

Therefore we conclude that

John Doe is cited in Rice 2007.

...

Knox 2003 because it cites ...

Therefore we conclude that

John Doe is cited in Knox 2003.

How many publications cite John Doe?

250

readings in courses

Therefore we need to

Assess how many courses use publications by John Doe as readings.

Problem Reduction

Solution Synthesis

Detailed Reduction and Synthesis Logic

We need to

Assess whether John Doe would be a good PhD advisor for Bob Sharp with respect to research contributions.

John Doe would be a very good PhD advisor for Bob Sharp with respect to research contributions.

Which is a criterion for assessing research contributions?

Very good because the publications by John Doe are highly cited and are used in courses.

citations in publications

What is the level of research contributions of John Doe?

Therefore we need to

Assess how cited John Doe is.

John Doe is cited in 250 publications.

250

What publication cites John Doe?

How many publications cite John Doe?

Rice 2007 cites Doe 2000 ...

Therefore we conclude that

John Doe is cited in Rice 2007.

...

Knox 2003 cites Doe 2001 ...

Therefore we conclude that

John Doe is cited in Knox 2003.

readings in courses

Therefore we need to

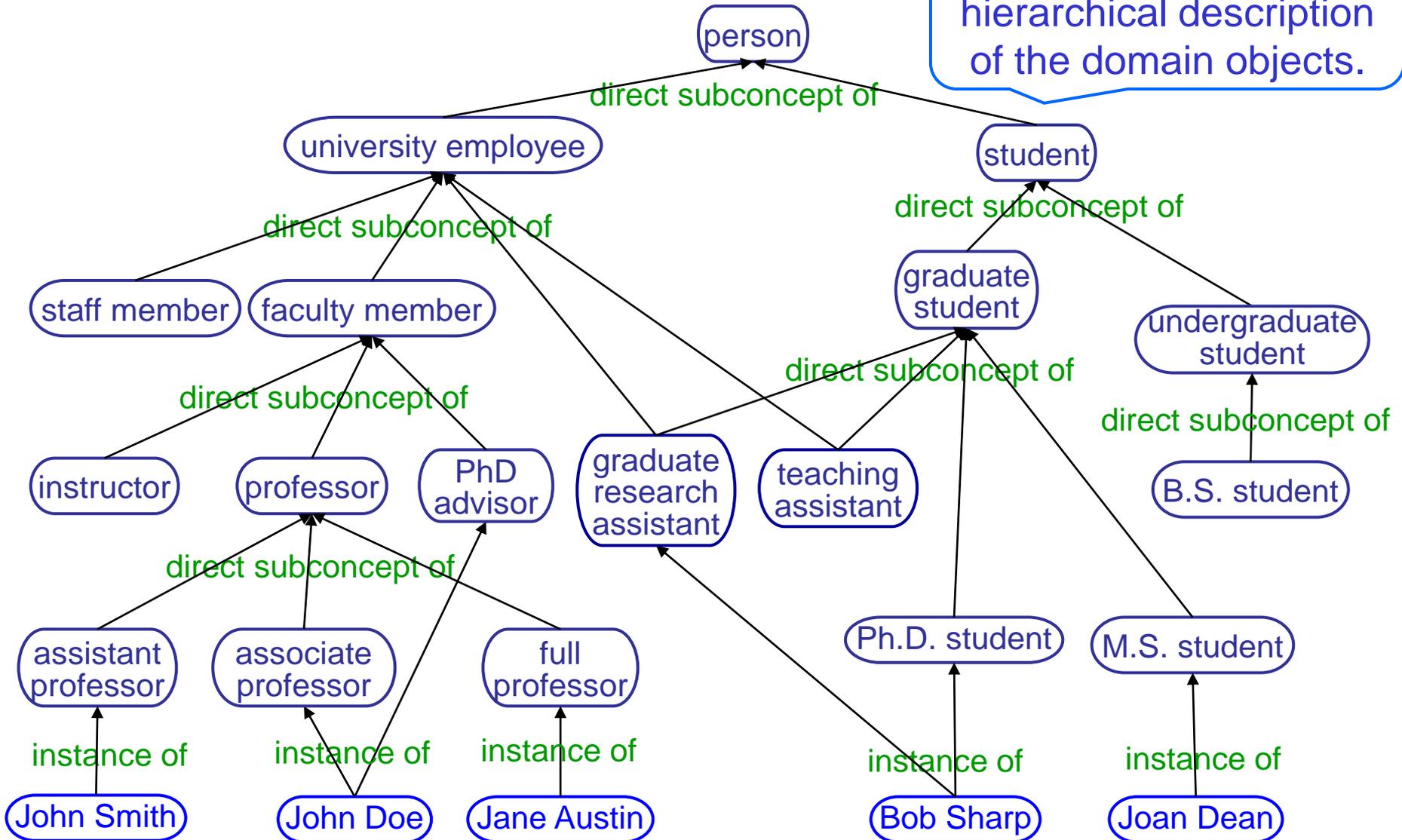
Assess how many courses use papers by John Doe as readings.

5 courses use publications by Joe Doe as reading material.

Solution Synthesis

Knowledge Base = Object Ontology + Rules

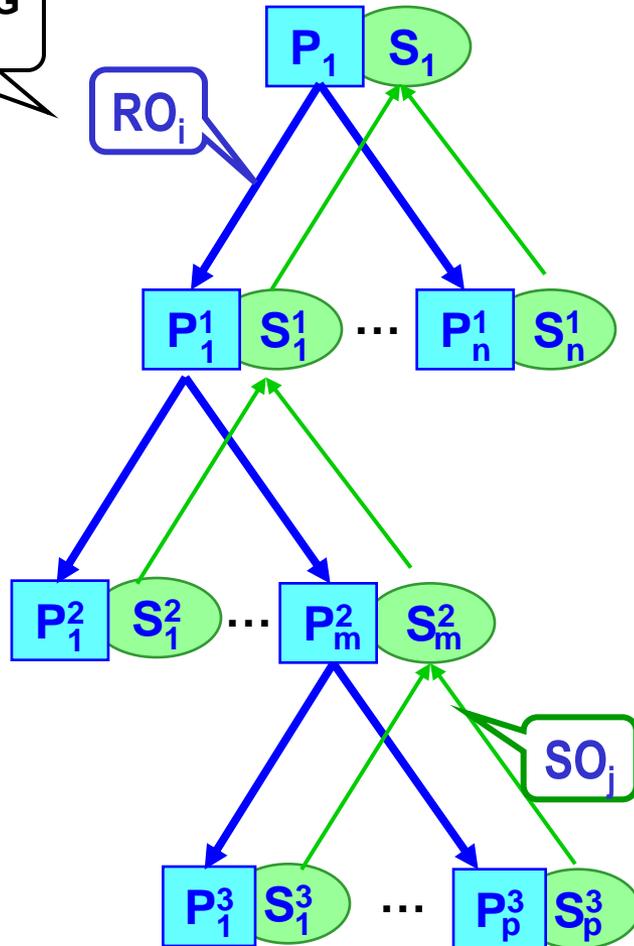
The **object ontology** is a hierarchical description of the domain objects.



Knowledge Base = Object Ontology + Rules

The **rules** specify general problem solving steps described with the objects from the ontology.

REASONING TREE



RULE

IF
Assess ?O1 as a potential PhD advisor for ?O2

Question

Is ?O2 interested in the area of expertise of ?O1 ?

Answer

Yes, because ?O2 is interested in ?O3 which is the area of expertise of ?O1.

Condition

*?O1 is PhD advisor
is expert in ?O3
?O2 is PhD student
is interested in ?O3
?O3 is PhD research area*

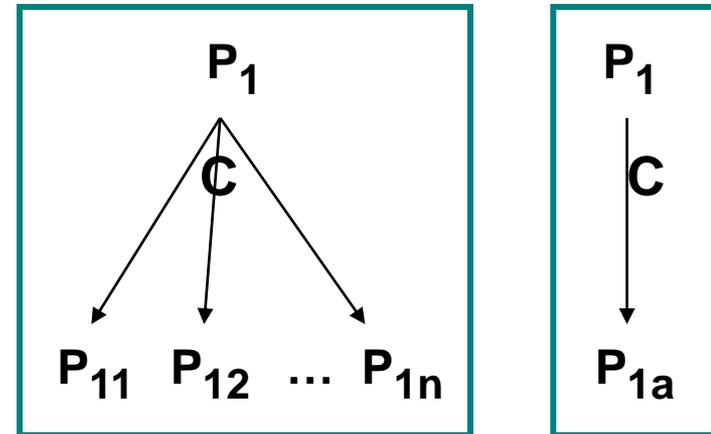
THEN

Assess ?O1 as a potential PhD advisor for ?O2 in ?O3

Problem Reduction Rules

A problem reduction rule is an IF-THEN structure that expresses the condition C under which a problem P_1 can be reduced to the simpler problems P_{11} , P_{12} , ..., P_{1n} .

This means that one can solve P_1 by solving P_{11} , P_{12} , ..., P_{1n} .



Partially Learned Problem Reduction Rule

Rule Viewer

REDUCTION RULE DDR.00000 FORMAL DESCRIPTION

IF: Assess ?O1 as a potential PhD advisor for ?O2.

Q: Is ?O2 interested in the area of expertise of ?O1?

A: Yes, because ?O2 is interested in ?O3 which is the area of expertise of ?O1.

MAIN CONDITION

Var	Lower Bound	Upper Bound
?O1	(PhD advisor, associate professor)	(person)
?O2	(PhD student)	(person)
?O3	(computer science)	(PhD research area)

Var	Relationship	Var
?O2	is interested in	?O3
?O1	is expert in	?O3

THEN: Assess ?O1 as a potential PhD advisor for ?O2 in ?O3.

Informal applicability condition

Formal applicability condition (partially learned)

Reduction Rule with Except When Conditions

IF

<problem>

Condition

<condition 1>

Except when condition

<condition 2>

Except when condition

<condition n>

THEN

<subproblem 1>

...

<subproblem m>

In addition to the regular rule condition that needs to be satisfied, a rule may contain one or several except when conditions that should not be satisfied for the rule to be applicable.

Rule Application

Reasoning Step Reasoning Hierarchy Report Graphical Viewer

- Assess John Doe as a potential PhD advisor for Bob Sharp.
 - Is Bob Sharp interested in the area of expertise of John Doe?
 - Yes, because Bob Sharp is interested in Artificial Intelligence which is the area of expertise of John Doe.
 - Assess John Doe as a potential PhD advisor for Bob Sharp in Artificial Intelligence.
 - Is John Doe likely to stay on the faculty of George Mason University for the duration of Bob Sharp 's dissertation?
 - Yes, because John Doe has a tenured position which is a long term position.
 - Assess whether John Doe would be a good PhD advisor Bob Sharp in Artificial Intelligence.
 - Which is a PhD advisor quality criterion?
 - professional reputation
 - Assess whether John Doe would be a good PhD Bob Sharp with respect to professional reputati
 - Which is a PhD advisor quality criterion?
 - personality and compatibility with student
 - Which is a PhD advisor quality criterion?
 - quality of student results
 - Which is a PhD advisor quality criterion?
 - responsiveness to students
 - Which is a PhD advisor quality criterion?

Rule Viewer

REDUCTION RULE DDR.00000 FORMAL DESCRIPTION

IF: Assess ?O1 as a potential PhD advisor for ?O2.

Q: Is ?O2 interested in the area of expertise of ?O1?

A: Yes, because ?O2 is interested in ?O3 which is the area of expertise of ?O1.

MAIN CONDITION

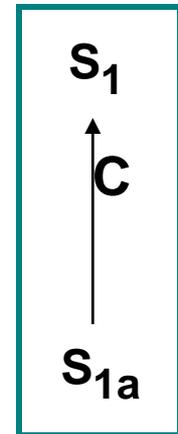
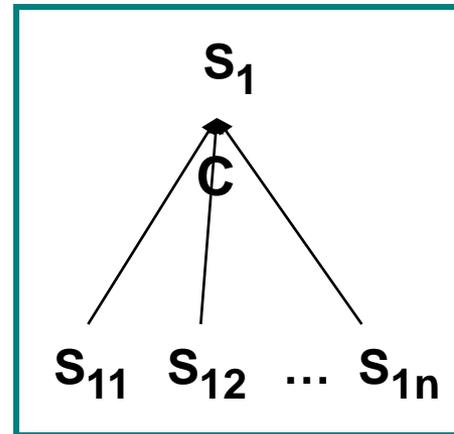
Var	Lower Bound	Upper Bound
?O1	(PhD advisor, associate professor)	(person)
?O2	(PhD student)	(person)
?O3	(computer science)	(PhD research area)

Var	Relationship	Var
?O2	is interested in	?O3
?O1	is expert in	?O3

THEN: Assess ?O1 as a potential PhD advisor for ?O2 in ?O3.

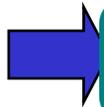
Solution Synthesis Rules

A solution synthesis rule is an IF-THEN structure that expresses the condition C under which the solutions $S_{11}, S_{12}, \dots, S_{1n}$ of the subproblems of P_1 can be combined into the solution S_1 of the problem P_1 .



Overview

Knowledge Base Organization



Reasoning Mechanisms

Disciple-COA: Critiquing as Expertise Problem

Disciple-WA: Workaround as Expertise Problem

Reading

Ontology Matching

Ontology matching allows one to look for instances of complex concepts in the object ontology (i.e. ask questions about the objects in the ontology).

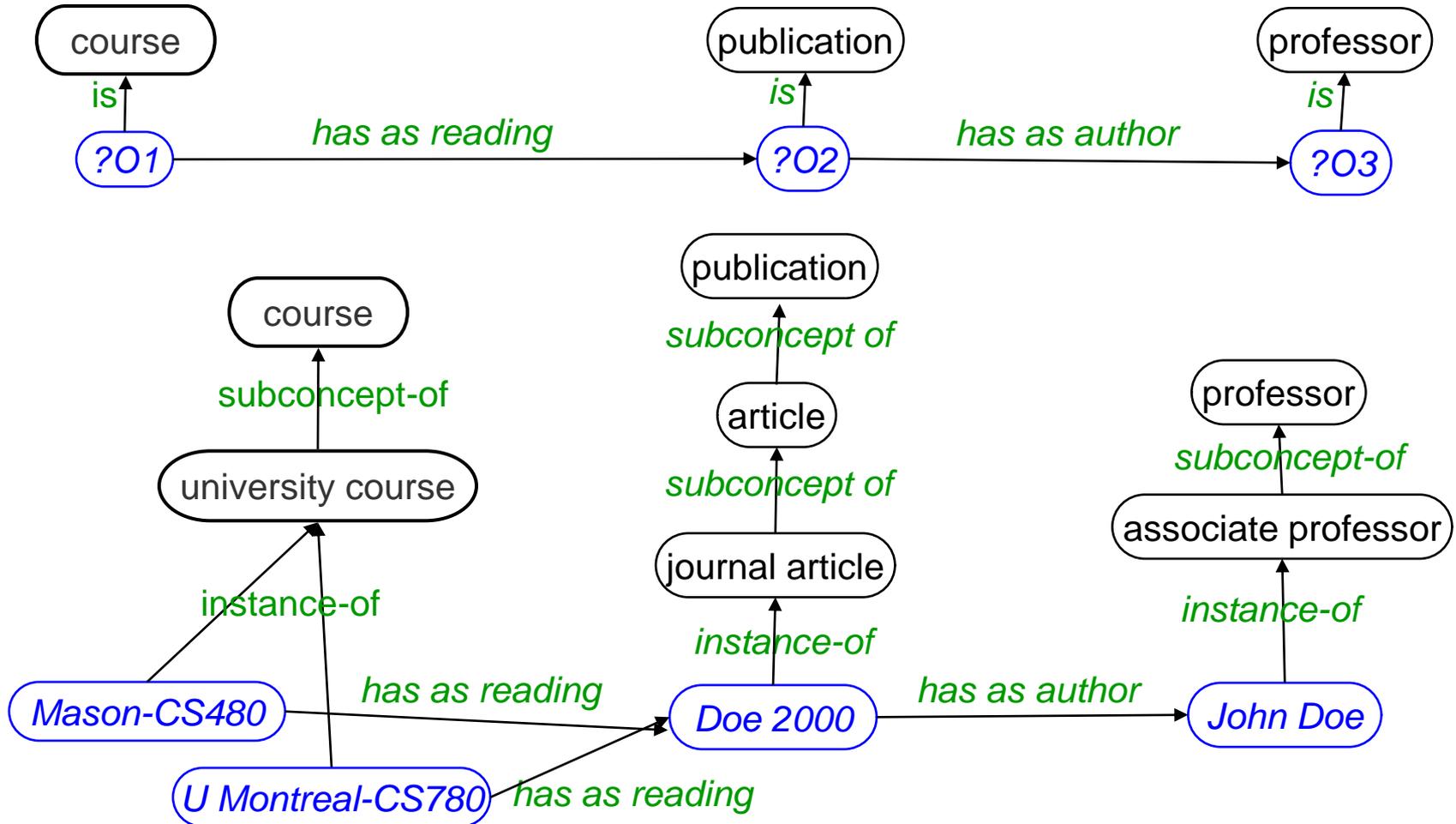
Example:

Is there a course that has as reading a publication by a professor?

Yes, Mason-CS480 that uses as reading Doe 2000 which is a journal article of John Doe who is a professor.

Ontology Matching: Example

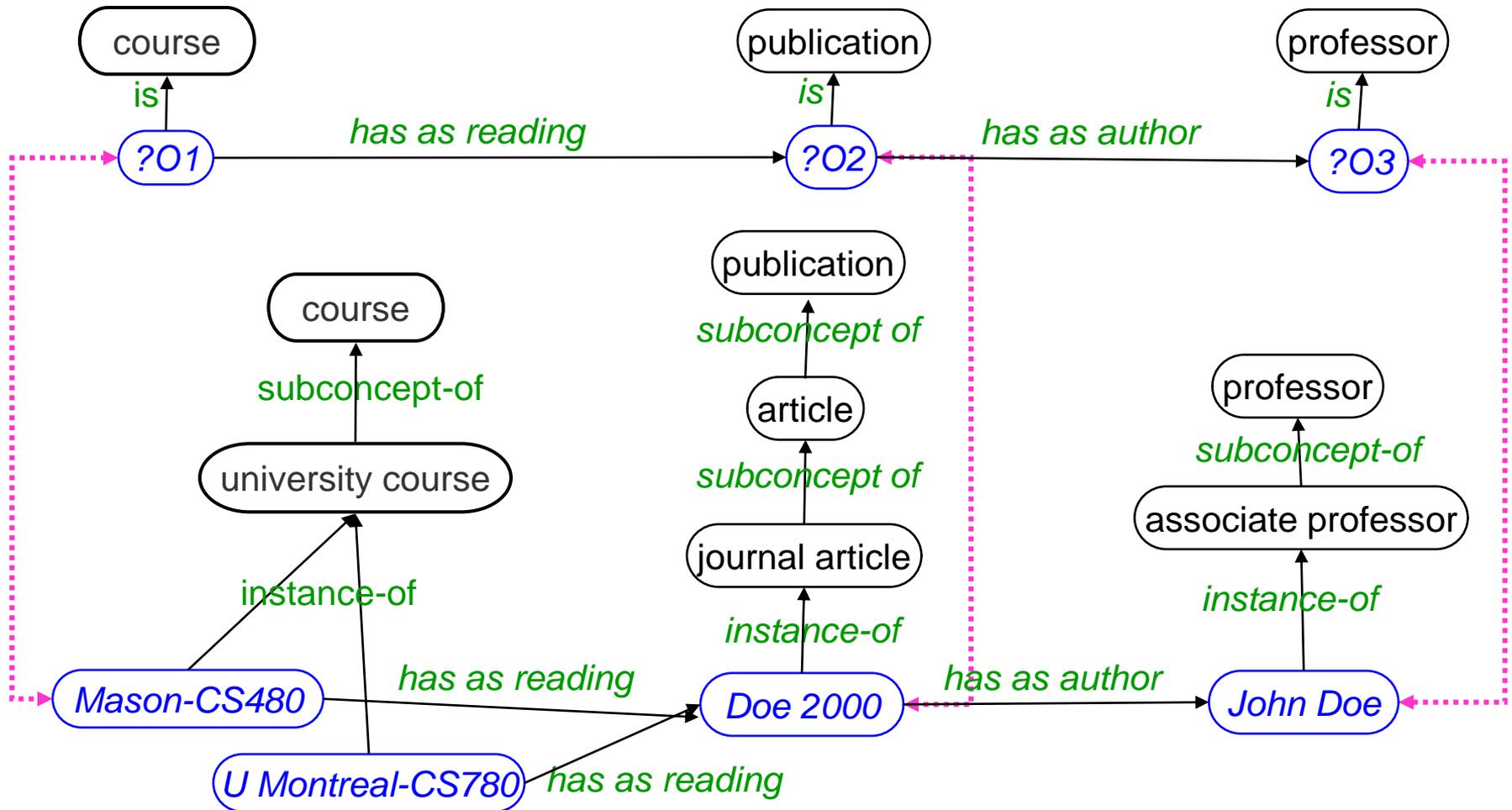
Is there a course that has as reading a publication by a professor?



Technique: Formulate the question as a general pattern to match with the object ontology.

Ontology Matching: Example

Q: Is there a course that has as reading a publication by a professor?

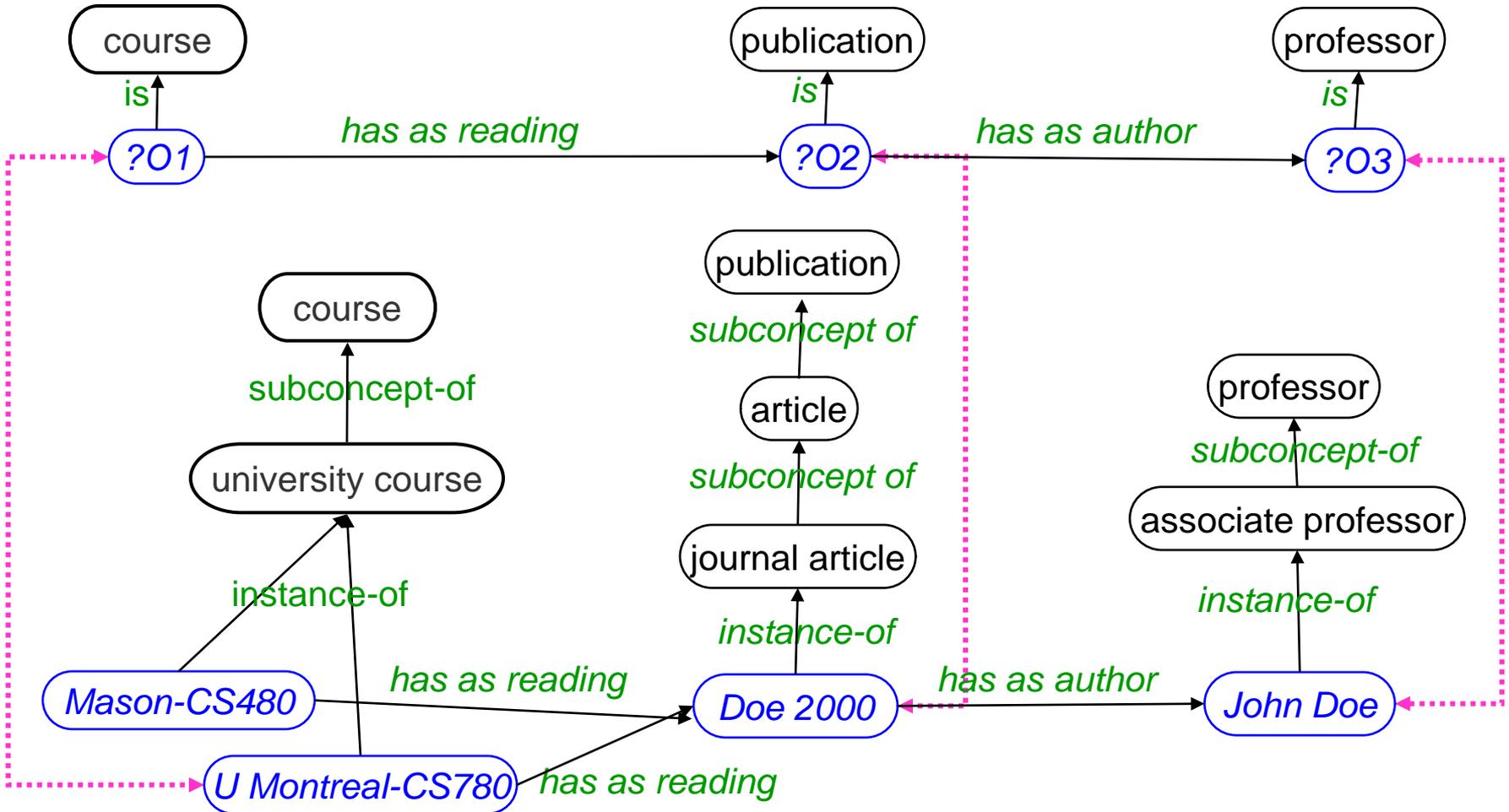


A: Mason-CS480 that uses as reading Doe 2000 which has John Doe as an author.

Is this the only answer?

Ontology Matching: Example

Q: Is there a course that has as reading a publication by a professor?

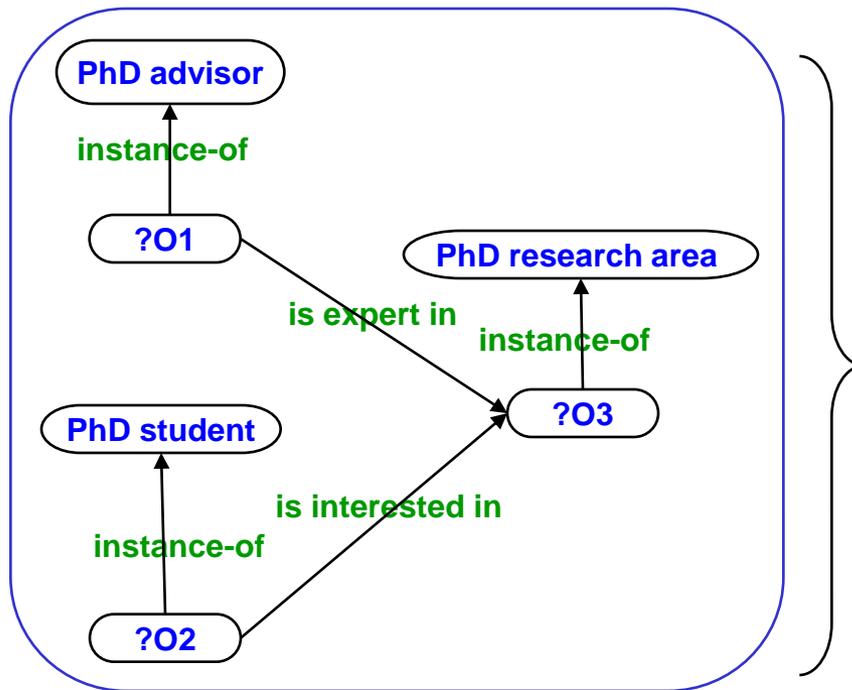


A: U Montreal-CS780 that uses as reading Doe 2000 which has John Doe as an author.

Illustration of the Problem Solving Process

Rule selection based on matching:

Rule condition



Assess John Doe as a potential PhD advisor for Bob Sharp.

?O1 ← John Doe
?O2 ← Bob Sharp

IF
Assess?O1 as a potential PhD advisor for ?O2

Question
Is ?O2 interested in the area of expertise of ?O1 ?

Answer
Yes, because ?O2 is interested in ?O3 which is the area of expertise of ?O1.

Condition
?O1 is PhD advisor
is expert in ?O3
?O2 is PhD student
is interested in ?O3
?O3 is PhD research area

THEN
Assess ?O1 as a potential PhD advisor for ?O2 in ?O3

When is the rule applicable?

Explanation

Let us now see how the agent uses the rules in problem solving.

Let us suppose that the current problem is:

Assess John Doe as a potential PhD advisor for Bob Sharp.

The agent will look into its knowledge base for a rule that has this type of problem in the IF part. Such a rule is shown in the right hand side of the slide. As one can see, the IF problem becomes identical with the problem to be solved if ?O1 is replaced with John Doe and ?O2 is replaced with Bob Sharp.

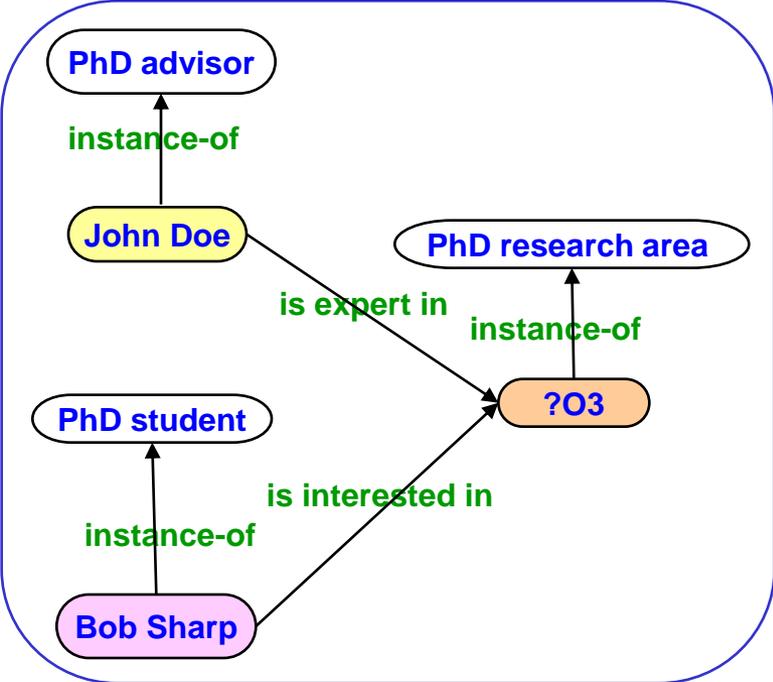
Next the agent has to check that the condition of the rule is satisfied for these values of ?O1 and ?O2.

The left hand side of the slide shows what condition needs to be satisfied by ?O1 (John Doe), ?O2 (Bob Sharp) and ?O3.

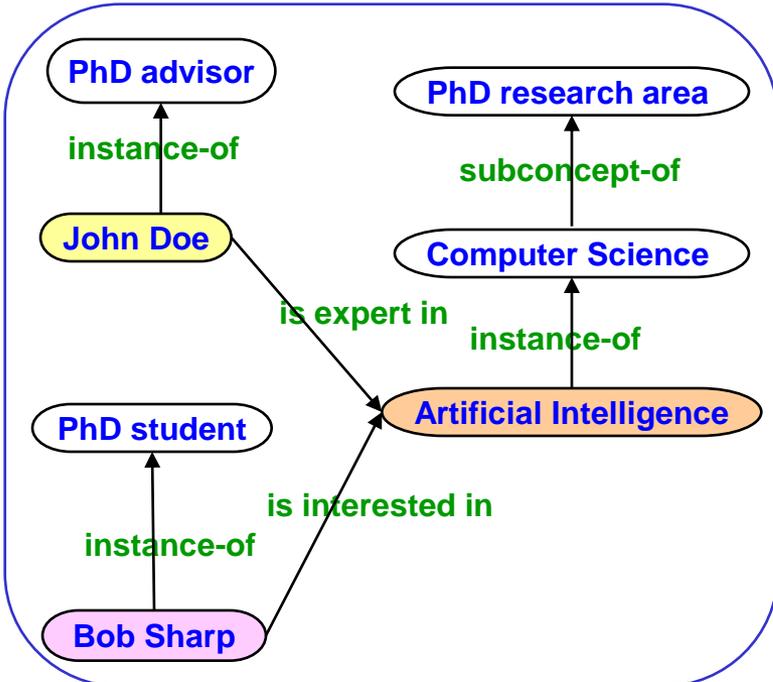
This condition is satisfied if there is any instance of ?O3 in the object ontology that satisfies all the relationships specified in the left hand side of the slide.

Ontology Matching

Rule condition



Object ontology



?O1 ← John Doe
?O2 ← Bob Sharp
?O3 ← Artificial Intelligence

How is this matching performed?
Is it efficient?

Explanation

The partially instantiated condition of the rule, shown in the left hand side of the previous slide, is matched successfully with the object ontology fragment shown in the right hand side of the slide.

?O3 matches Artificial Intelligence.

Both ?O3 and Artificial Intelligence are PhD research areas. Indeed, Artificial Intelligence is an instance of Computer Science, which is a subconcept of PhD research area.

Both ?O3 and Artificial Intelligence are the values of the features:

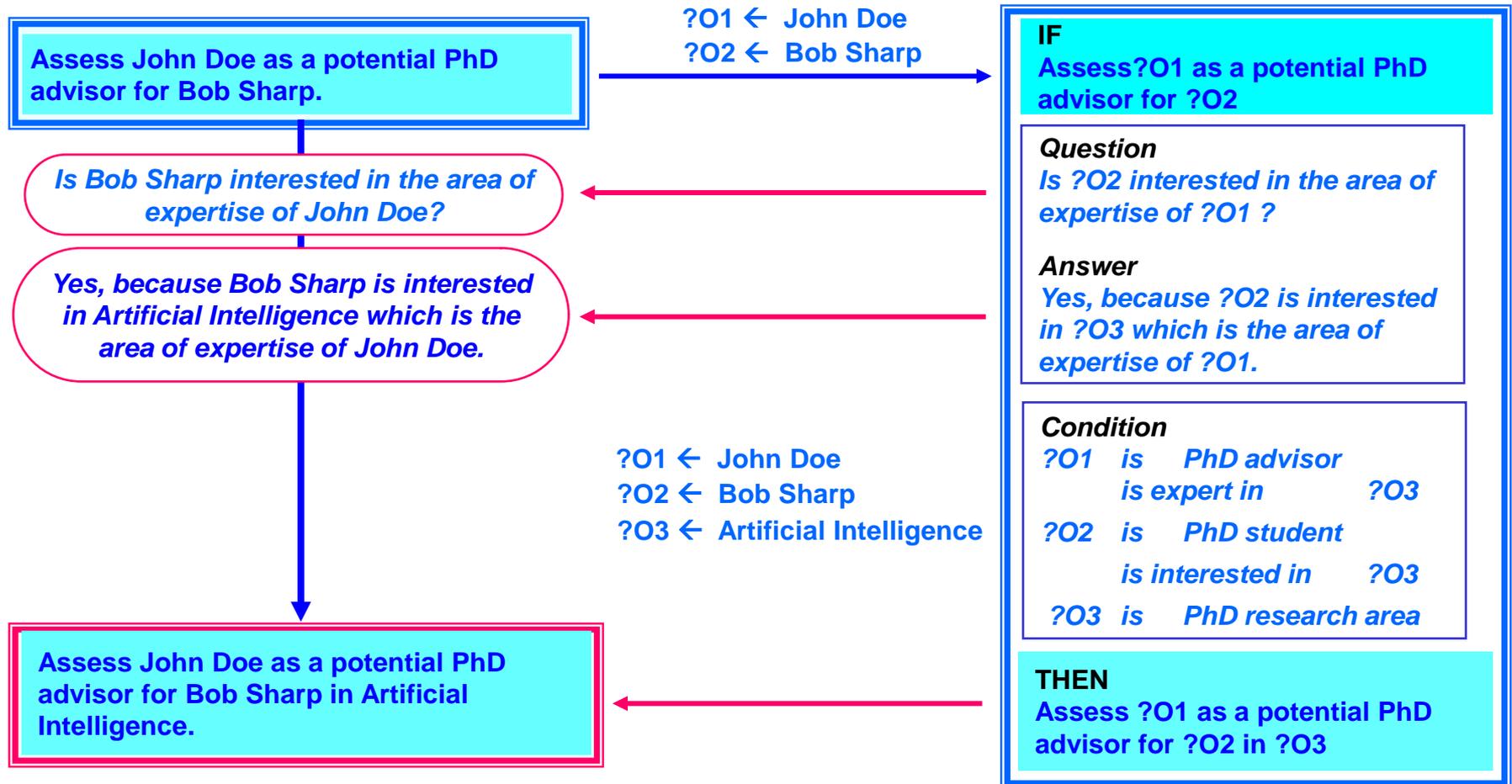
John Doe	is expert in	Artificial Intelligence (?O3)
Bob Sharp	is interested in	Artificial Intelligence (?O3)

As the result of this matching, the rule's ?O3 variable is instantiated as follows:

?O3 ← Artificial Intelligence

Application of a Rule in Problem Solving

How is the rule applied in problem solving?



Explanation

As shown, the rule's condition is satisfied for the following instantiations of the variables:

?O1 ← John Doe

?O2 ← Bob Sharp

?O3 ← Artificial Intelligence

Therefore the IF problem

Assess John Doe as a potential PhD advisor for Bob Sharp.

is reduced to the following THEN problem:

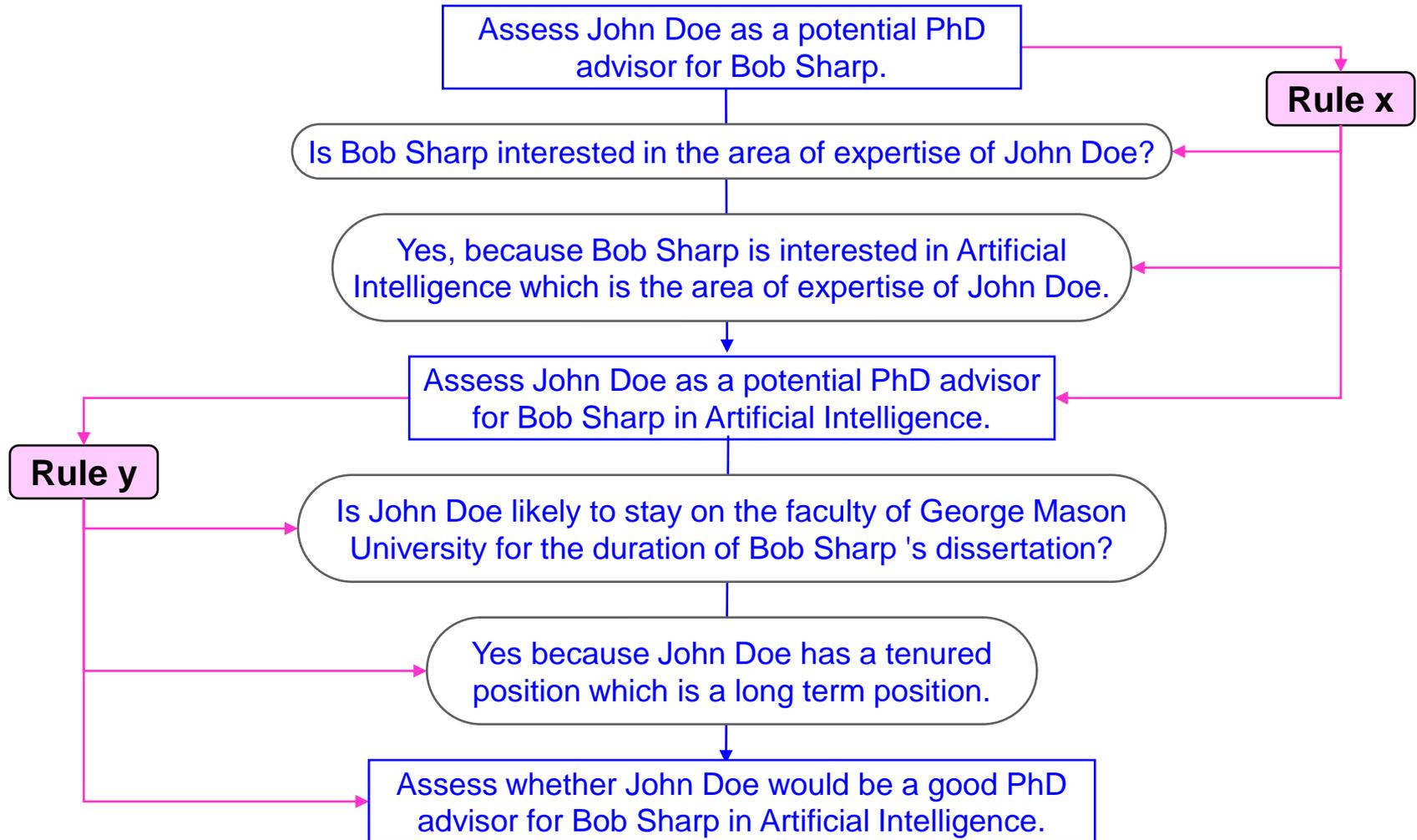
Assess John Doe as a potential PhD advisor for Bob Sharp
in Artificial Intelligence.

Disciple also instantiates the Question/Answer pair of the rule:

Is Bob Sharp interested in the area of expertise of John Doe?

Yes, because Bob Sharp is interested in Artificial Intelligence which is the area of expertise of John Doe.

Successive Rule Applications



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.”

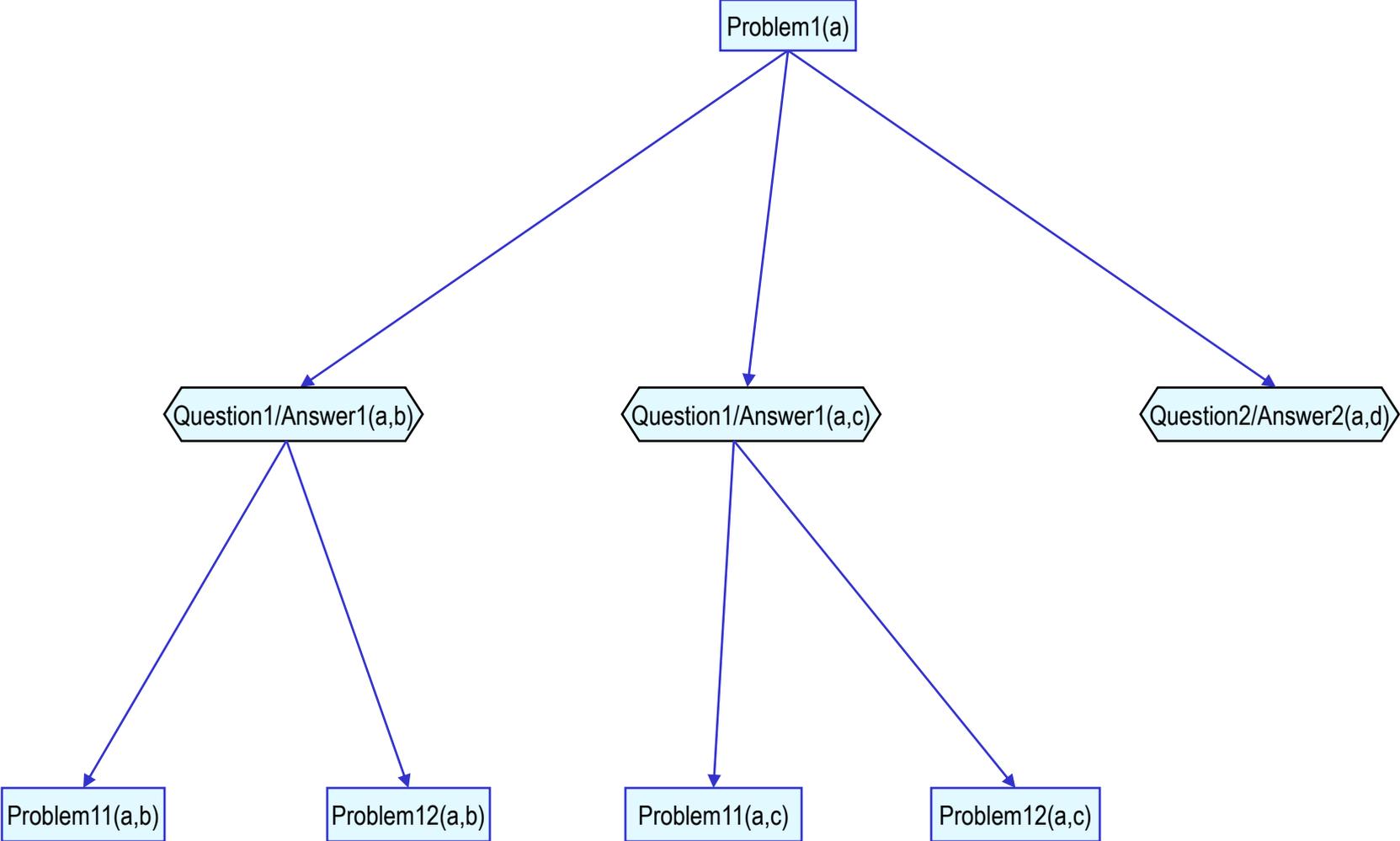
Alvin Toffler, *Science and Change*, Forward to Ilya Prigogine and Isabelle Stengers *“Order Out of Chaos: Man’s New Dialogue with Nature”*, Bantam Books, 1984.



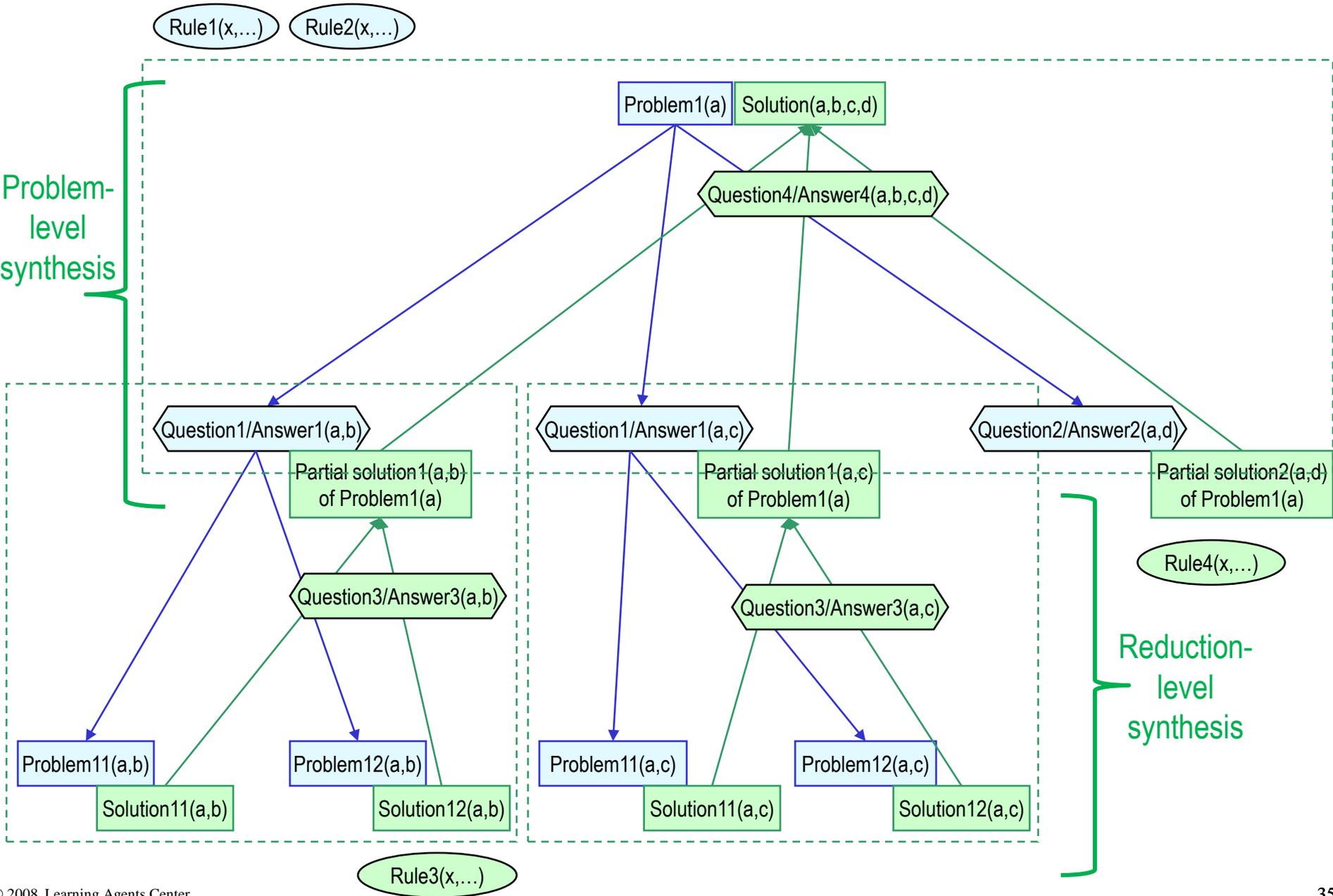
Alvin Toffler

Problem Reduction

Rule1(x,...) Rule2(x,...)



Solution Synthesis



Explanation

Let us consider $\text{Problem1}(a)$, an instance of a general problem $\text{Problem1}(x)$.

Let us further assume that there are two reduction rules, $\text{Rule1}(x, \dots)$ and $\text{Rule2}(x, \dots)$, that are applicable to reduce this problem as follows:

- 1) An instance of $\text{Rule1}(x, \dots)$ reduces $\text{Problem1}(a)$ to $\text{Problem11}(a,b)$ and $\text{Problem12}(a,b)$.
- 2) Another instance of $\text{Rule1}(x, \dots)$ reduces $\text{Problem1}(a)$ to $\text{Problem11}(a,c)$ and $\text{Problem12}(a,c)$.
- 3) An instance of $\text{Rule2}(x, \dots)$ reduces $\text{Problem1}(a)$ to $\text{Problem13}(a,d)$.

Each such reduction will lead to a partial solution of $\text{Problem1}(a)$, as explained in the following.

Let us assume that $\text{Problem11}(a,b)$ has the solution $\text{Solution11}(a,b)$ and $\text{Problem12}(a,b)$ has the solution $\text{Solution12}(a,b)$.

Let us also assume that the solution synthesis rule $\text{Rule3}(x, \dots)$ will synthesize (compose) $\text{Solution11}(a,b)$ and $\text{Solution12}(a,b)$ into $\text{Partial solution1}(a,b)$ of $\text{Problem1}(a)$. We associate this partial solution with $\text{Question1/Answer1}(a,b)$.

Let us further assume that the same rule $\text{Rule3}(x, \dots)$ will synthesize (compose) $\text{Solution11}(a,c)$ and $\text{Solution12}(a,c)$ into $\text{Partial solution1}(a,c)$ of $\text{Problem1}(a)$. We associate this partial solution with $\text{Question1/Answer1}(a,c)$.

Similarly, let us assume that we also obtain $\text{Partial solution2}(a,d)$ associated with $\text{Question2/Answer2}(a,d)$.

The solution of $\text{Problem1}(a)$ will be obtained by composing all its partial solutions, $\text{Partial solution1}(a,b)$, $\text{Partial solution1}(a,c)$ and $\text{Partial solution2}(a,d)$, based on another synthesis rule.

Explanation

Thus we distinguish two types of solution syntheses (compositions):

- 1) A reduction-level synthesis which is associated with a specific reduction and leads to a partial solution of a problem.
- 2) A problem-level synthesis which synthesizes the partial solutions of a problem into its complete solution.

Consequently, there are two types of synthesis rules:

- 1) Reduction-level synthesis rules which are associated with reduction rules.
- 2) Problem-level synthesis rules which are associated with the problems.

There may be several reduction-level synthesis rules associated with a reduction rule. They may lead to several partial solutions of the IF Problem from the reduction rule. All of them will need to be composed to produce the complete solution of the IF Problem.

There may also be several Problem-level synthesis rules associated with a given Problem. They will lead to alternative complete solutions of the Problem.

The following slides illustrate this process.

Problem Reduction: Example

Problem1(a)

Assess whether *Al Qaeda* considers self defense as a reason to obtain nuclear weapons.

Is there any potentially relevant piece of evidence?
EVD-Dawn-Mir01-01c which mentions that *Al Qaeda* would use nuclear weapons to defend itself.

Problem11(a,b)

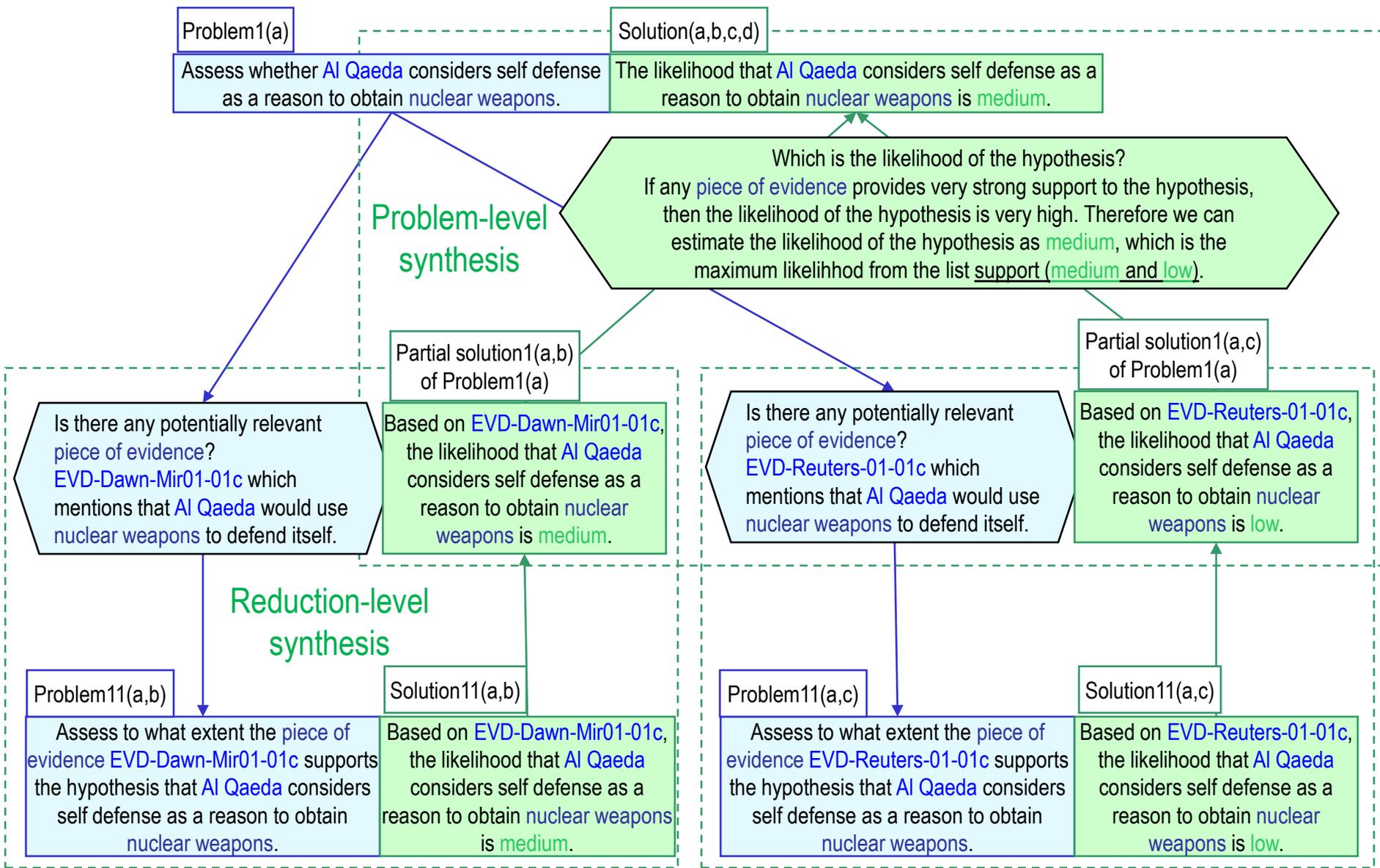
Assess to what extent the piece of evidence *EVD-Dawn-Mir01-01c* supports the hypothesis that *Al Qaeda* considers self defense as a reason to obtain nuclear weapons.

Is there any potentially relevant piece of evidence?
EVD-Reuters-01-01c which mentions that *Al Qaeda* would use nuclear weapons to defend itself.

Problem11(a,c)

Assess to what extent the piece of evidence *EVD-Reuters-01-01c* supports the hypothesis that *Al Qaeda* considers self defense as a reason to obtain nuclear weapons.

Solution Synthesis: Example



Explanation

Let us consider the problem

“Assess whether [Al Qaeda](#) considers self defense as a reason to obtain [nuclear weapons](#).”

To facilitate the correspondence with the general case we have annotated the elements of this illustration with the labels from the general case.

Notice that, in this illustration, there is only one rule that reduces Problem1, but there are two reductions, each corresponding to a different instantiation of the reduction rule.

Notice also that this rule reduces Problem1 to a single problem, Problem11. However, we still need to have a reduction-level synthesis to obtain Partial solution1(a,b) of Problem1(a) from Solution11(a,b). In many cases these solutions are identical. However, sometimes one may wish to define Partial solution1(a,b) as a reformulation of Solution11(a,b). In this illustration there is no question/answer pair associated with the reduction-level synthesis.

Finally, notice that Solution(a,b,c,d) is obtained as a composition of Partial solution1(a,b) and Partial solution1(a,c).

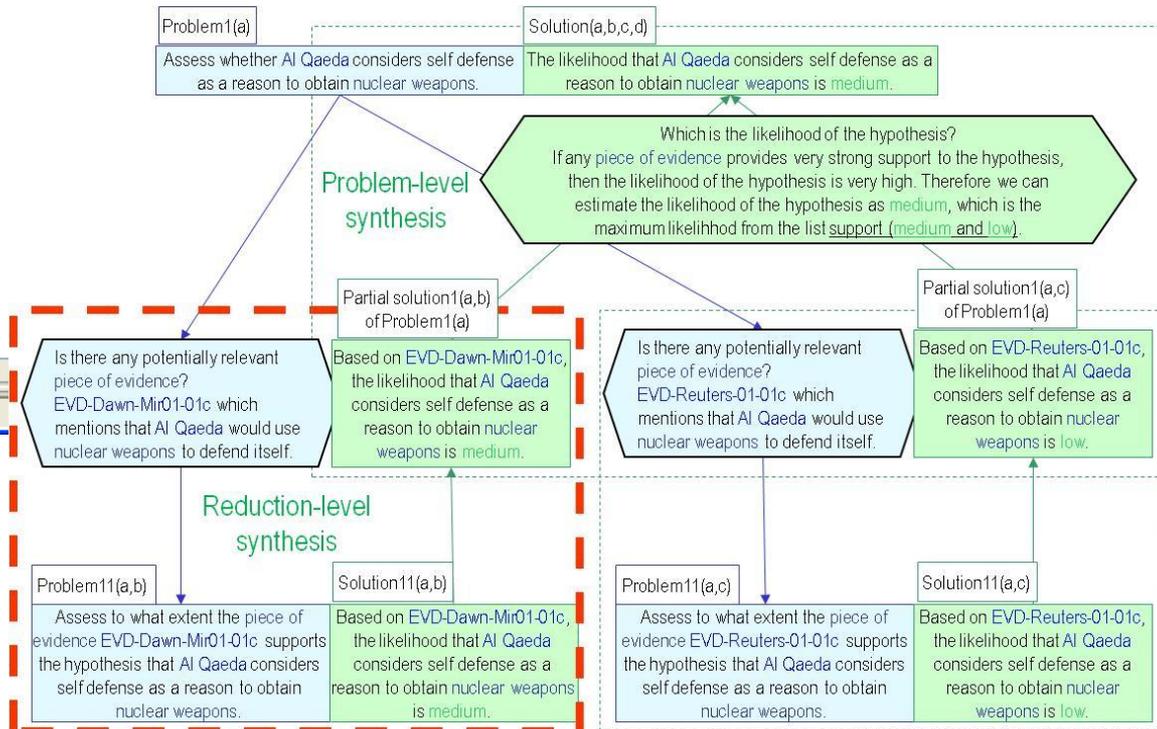
The following two slides illustrate the definition of these compositions (syntheses) using the modeling editor of Disciple.

Reduction-level Synthesis

Reasoning Hierarchy Reasoning Step Graphical Viewer Report

Default Viewer Advanced Viewer

<p>Task</p> <p>Assess whether Al Qaeda considers self defense as a reason to obtain nuclear weapons.</p>	<p>Reduction Solution</p> <p>Based on EVD-Dawn-Mir01-01c, the likelihood that Al Qaeda considers self defense as a reason to obtain nuclear weapons is medium.</p>
<p>Question</p> <p>Is there any potentially relevant piece of evidence?</p>	<p>Composition Question</p>
<p>Answer</p> <p>EVD-Dawn-Mir01-01c which mentions that Al Qaeda would use nuclear weapons to defend itself.</p>	<p>Composition Answer</p>
<p>Sub-task</p> <p>Assess to what extent the piece of evidence EVD-Dawn-Mir01-01c supports the hypothesis that Al Qaeda considers self defense as a reason to obtain nuclear weapons.</p>	<p>Sub-solution</p> <p>Based on EVD-Dawn-Mir01-01c, the likelihood that Al Qaeda considers self defense as a reason to obtain nuclear weapons is medium.</p>



Problem-level Synthesis

Reasoning Hierarchy Reasoning Step Graphical Viewer Report

Task
Assess whether **Al Qaeda** considers self defense as a reason to obtain nuclear weapons.

Task Solution
The likelihood that **Al Qaeda** considers self defense as a reason to obtain nuclear weapons is **medium**.

Question
Is there any potentially relevant **piece of evidence**?

Answer
EVD-Dawn-Mir01-01c which mentions that **Al Qaeda** would use nuclear weapons to defend itself.

Composition Question
Which is the likelihood of the hypothesis?

Composition Answer
If any **piece of evidence** provides very strong support to the hypothesis, then the likelihood of the hypothesis is very high. Therefore we can estimate the likelihood of the hypothesis as **medium**, which is the maximum likelihood from the list support (**medium** and **low**).

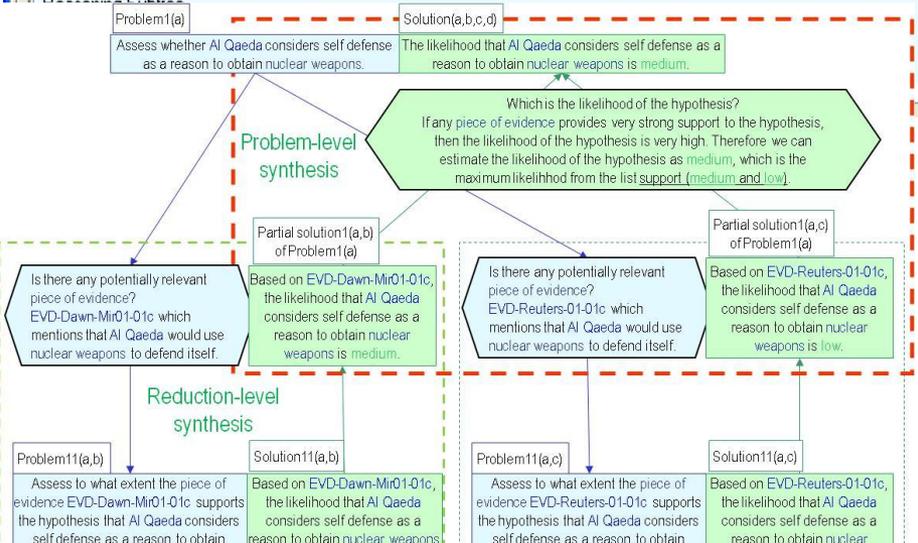
Reasoning Subtree

Reasoning Subtree Solution
Based on **EVD-Dawn-Mir01-01c**, the likelihood that **Al Qaeda** considers self defense as a reason to obtain nuclear weapons is **medium**.

Question
Is there any potentially relevant **piece of evidence**?

Answer
EVD-Reuters-01-01c which mentions that **Al Qaeda** would use nuclear weapons to defend itself.

Reasoning Subtree Solution
Based on **EVD-Reuters-01-01c**, the likelihood that **Al Qaeda** considers self defense as a reason to obtain nuclear weapons is **low**.



options

Problem Reduction: Example

Problem1(a)
Assess to what extent the piece of evidence EVD-Dawn-Mir01-01c supports the hypothesis that Al Qaeda considers self defense as a reason to obtain nuclear weapons.

What factors determine how a piece of evidence supports a hypothesis?
The information provided by the piece of evidence and the extent to which it can be trusted.

Problem11(a,b)
Assess to what extent EVD-Dawn-Mir01-01c supports the hypothesis that Al Qaeda considers self defense as a reason to obtain nuclear weapons, assuming that we believe the information provided by EVD-Dawn-Mir01-01c.

Problem12(a,b)
Assess the credibility of EVD-Dawn-Mir01-01c.

Explanation

Let us consider the problem

“Assess to what extent the [piece of evidence EVD-Dawn-Mir01-01c](#) supports the hypothesis that [Al Qaeda](#) considers self defense as a reason to obtain [nuclear weapons](#).”

To facilitate the correspondence with the general case we have annotated the elements of this illustration with the labels from the general case.

Notice that, in this illustration, there is only one rule that reduces Problem1 and one instantiation of the rule.

Notice also that this rule reduces Problem1 to two problems, Problem11 and Problem12.

However, we still need to have a problem-level synthesis (composition) to obtain Solution(a,b,c,d) from Partial solution1(a,b). Notice that, when we define the question/answer pair of the problem-level synthesis, we have to consider the general case where there might be several partial solutions of Problem1 that need to be composed. Indeed, Disciple will learn a general synthesis rule from this example and this rule would need to be applicable both in the case of a single solution and in the case of several partial solutions.

The following two slides illustrate the definition of these compositions (syntheses) using the modeling editor of Disciple.

Reduction-level Synthesis

repository\IA Oct 2006\AI Qaida

Teaching

Teach the agent: << >>

Teaching type: Both Teaching mode: Modeling

Reasoning Hierarchy Reasoning Step Graphical Viewer Report

Default Viewer Advanced Viewer

Task Assess to what extent the piece of evidence EVD-Dawn-Mir01-01c supports the hypothesis that Al Qaeda considers self defense as a reason to obtain nuclear weapons .	Reduction Solution Based on EVD-Dawn-Mir01-01c , the likelihood that Al Qaeda considers self defense as a reason to obtain nuclear weapons is medium .
Question What factors determine how a piece of evidence supports a hypothesis?	Composition Question Which is the likelihood of the hypothesis?
Answer The information provided by the piece of evidence and the extent to which it can be trusted.	Composition Answer medium which is the minimum of information support and credibility , from the list support for factors (very high and medium) .
Sub-task Assess to what extent EVD-Dawn-Mir01-01c supports the hypothesis that Al Qaeda considers self defense as a reason to obtain nuclear weapons , assuming that we believe the information provided by EVD-Dawn-Mir01-01c .	Sub-solution Based only on the information from EVD-Dawn-Mir01-01c , the likelihood that Al Qaeda considers self defense as a reason to obtain nuclear weapons is very high .
Sub-task Assess the credibility of EVD-Dawn-Mir01-01c .	Sub-solution The credibility of EVD-Dawn-Mir01-01c is medium .

options

Q/A Ontology Specs Explanations Default Explanations Viewer

Problem-level Synthesis

repository\IA Oct 2006\AI Qaida

Teaching

Teach the agent: << >>

Teaching type: Both Teaching mode: Modeling

Reasoning Hierarchy Reasoning Step Graphical Viewer Report

Task ↑

Assess to what extent the [piece of evidence EVD-Dawn-Mir01-01c](#) supports the hypothesis that [Al Qaeda](#) considers self defense as a reason to obtain [nuclear weapons](#).

Task Solution ↑

Based on [EVD-Dawn-Mir01-01c](#), the likelihood that [Al Qaeda](#) considers self defense as a reason to obtain [nuclear weapons](#) is [medium](#).

Composition Question

Which is the likelihood of the hypothesis?

Composition Answer

[medium](#) which is the minimum likelihood from the list [support \(medium\)](#).

Question

What factors determine how a [piece of evidence](#) supports a hypothesis?

Answer ↕

The information provided by the [piece of evidence](#) and the extent to which it can be trusted.

Reasoning Subtree

Reasoning Subtree Solution ↕

Based on [EVD-Dawn-Mir01-01c](#), the likelihood that [Al Qaeda](#) considers self defense as a reason to obtain [nuclear weapons](#) is [medium](#).

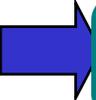
options

Q/A Ontology Specs Explanations Default Explanations Viewer

Overview

Knowledge Base Organization

Reasoning Mechanisms

 **Disciple-COA: Critiquing as Expertise Problem**

Disciple-WA: Workaround as Expertise Problem

Reading

Critiquing As an Expertise Task

Critiquing means expressing judgments about something according to certain standards.

Example:

Identifying the strengths and weaknesses of a military course of action with respect to the principles of war and the tenets of army operations.

For instance, assess a particular course of action with respect to the Principle of Surprise.

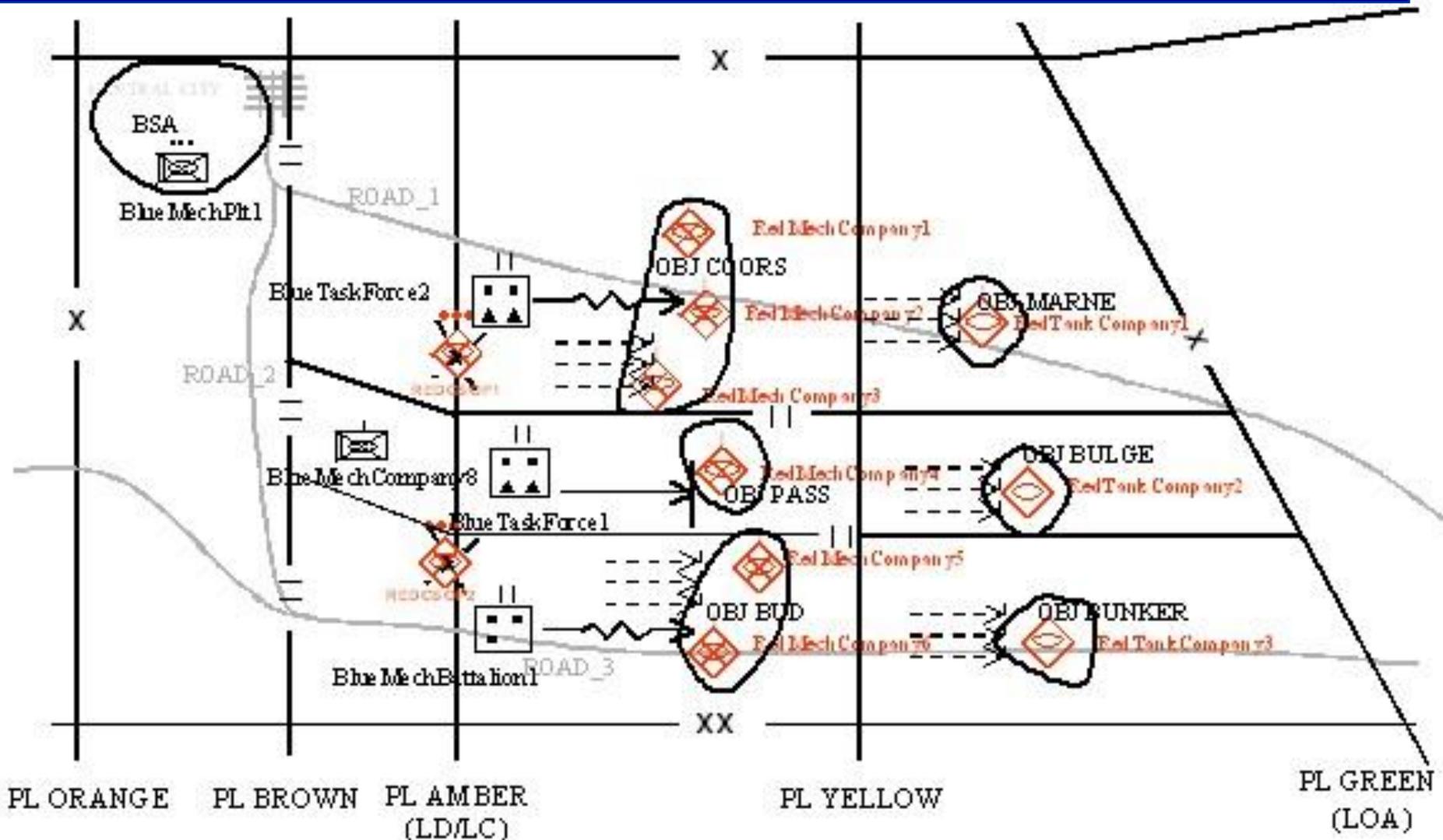
The Course of Action Critiquing Agent

Source: Challenge problem for the DARPA's High Performance Knowledge Base (HPKB) program.

Background: A military course of action (COA) is a preliminary outline of a plan for how a military unit might attempt to accomplish a mission. After receiving orders to plan for a mission, a commander and staff analyze the mission, conceive and evaluate potential COAs, select a COA, and prepare a detailed plans to accomplish the mission based on the selected COA. The general practice is for the staff to generate several COAs for a mission, and then to make a comparison of those COAs based on many factors including the situation, the commander's guidance, the principles of war, and the tenets of army operations. The commander makes the final decision on which COA will be used to generate his or her plan based on the recommendations of the staff and his or her own experience with the same factors considered by the staff.

Task: Identify strengths and weaknesses in a COA, based on the principles of war and the tenets of army operations.

COA411 – The Sketch



Graphical depiction of a preliminary plan. It includes enough of the high level structure and maneuver aspects of the plan to show how the actions of each unit fit together to accomplish the overall purpose.

COA411 – The Statement

Mission:	BLUE-BRIGADE2 attacks (BLUE-BRIGADE-OP) to penetrate (BLUE-BRIGADE-TASK) RED-MECH-REGIMENT2 at 130600 Aug in order to enable (ENABLE-MILITARY-PURPOSE1) the completion of seize (SEIZE2) OBJ-SLAM by BLUE-ARMOR-BRIGADE1.
Close:	<p>BLUE-TASK-FORCE1, a balanced task force (MAIN-EFFORT1) attacks (ATTACK2) to penetrate (PENETRATE1) RED-MECH-COMPANY4, then clears (CLEAR1) RED-TANK-COMPANY2 in order to enable (ENABLE-MILITARY-PURPOSE2) the completion of seize (SEIZE2) OBJ-SLAM by BLUE-ARMOR-BRIGADE1.</p> <p>BLUE-TASK-FORCE2, a balanced task force (SUPPORTING-EFFORT1) attacks (ATTACK3) to fix (FIX1) RED-MECH-COMPANY1 and RED-MECH-COMPANY2 and RED-MECH-COMPANY3 in order to prevent (PREVENT-MILITARY-PURPOSE1) RED-MECH-COMPANY1 and RED-MECH-COMPANY2 and RED-MECH-COMPANY3 from interfering with conducts of the MAIN-EFFORT1, then clears (CLEAR2) RED-MECH-COMPANY1 and RED-MECH-COMPANY2 and RED-MECH-COMPANY3 and RED-TANK-COMPANY1.</p> <p>BLUE-MECH-BATTALION1, a mechanized infantry battalion (SUPPORTING-EFFORT2) attacks (ATTACK4) to fix (FIX2) RED-MECH-COMPANY5 and RED-MECH-COMPANY6 in order to prevent (PREVENT-MILITARY-PURPOSE4) RED-MECH-COMPANY5 and RED-MECH-COMPANY6 from interfering with conducts of the MAIN-EFFORT1, then clears (CLEAR3) RED-MECH-COMPANY5 and RED-MECH-COMPANY6 and RED-TANK-COMPANY3.</p>
Reserve:	The reserve, BLUE-MECH-COMPANY8, a mechanized infantry company, follows Main Effort (MAIN-EFFORT1), and is prepared to reinforce (REINFORCING-AMILITARY-FORCE1) MAIN-EFFORT1.
Security:	<p>SUPPORTING-EFFORT1 destroys (DESTROY1) RED-CSOP1 prior to begin moving across PL-AMBER by MAIN-EFFORT1 in order to prevent (PREVENT-MILITARY-PURPOSE3) RED-MECH-REGIMENT2 from observing (MILITARY-OBSERVE-ACTION1) MAIN-EFFORT1.</p> <p>SUPPORTING-EFFORT2 destroys (DESTROY2) RED-CSOP2 prior to begin moving across PL-AMBER by MAIN-EFFORT1 in order to prevent (PREVENT-MILITARY-PURPOSE6) RED-MECH-REGIMENT2 from observing (MILITARY-OBSERVE-ACTION2) MAIN-EFFORT1.</p>
Deep:	Deep operations will destroy (DESTROY3) RED-TANK-COMPANY1 and RED-TANK-COMPANY2 and RED-TANK-COMPANY3.
Rear:	BLUE-MECH-PLT1, a mechanized infantry platoon secures (SECURE1) the brigade support area.

Explains what the units will do to accomplish the assigned mission.

COA411 – The Statement (cont)

Fires:	Fires will suppress (SUPPRESS1) RED-MECH-COMPANY1 and RED-MECH-COMPANY2 and RED-MECH-COMPANY3 and RED-MECH-COMPANY4 and RED-MECH-COMPANY5 and RED-MECH-COMPANY6.
Obstacles:	
Risk:	
End State:	At the conclusion of this operation, BLUE-BRIGADE2 will enable(ENABLE-MILITARY-PURPOSE1) accomplishing conducts forward passage of lines through BLUE-BRIGADE2 by BLUE-ARMOR-BRIGADE1. MAIN-EFFORT1 will complete to clear(CLEAR1) RED-MECH-COMPANY4 and RED-TANK-COMPANY2. SUPPORTING-EFFORT1 will complete to clear(CLEAR2) RED-MECH-COMPANY1 and RED-MECH-COMPANY2 and RED-MECH-COMPANY3 and RED-TANK-COMPANY1. SUPPORTING-EFFORT2 will complete to clear(CLEAR3) RED-MECH-COMPANY5 and RED-MECH-COMPANY6 and RED-TANK-COMPANY3.

COA Critiquing Task

Answer each of the following questions:

Principles of War

To what extent does this course of action conform to the principle of

OBJECTIVE ?

OFFENSIVE ?

MASS ?

ECONOMY OF FORCE ?

MANEUVER ?

UNIT OF COMMAND ?

SIMPLICITY ?

SECURITY ?

SURPRISE ?

The principles of war provide general guidance for the conduct of war at the strategic, operational and tactical levels.

Tenets of Army Operations

To what extent does this course of action conform to the tenet of

AGILITY ?

DEPTH ?

INITIATIVE ?

SYNCRONIZATION ?

VERSATILITY ?

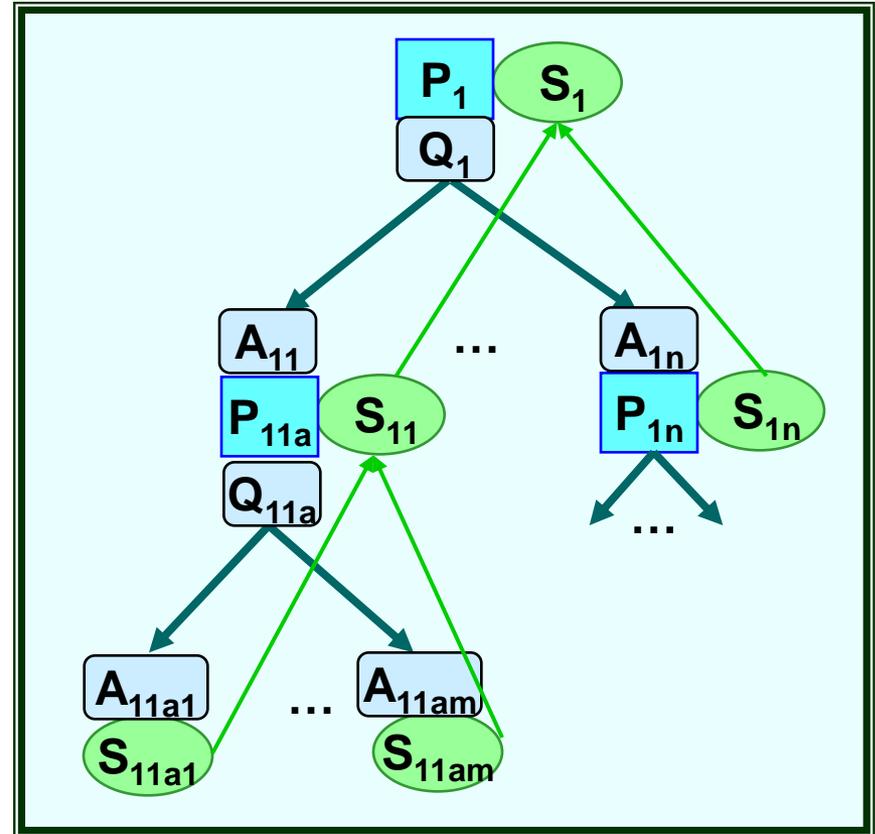
The tenets of army operations describe the characteristics of successful operations.

Modeling the Critiquing Process: Overview

To assess a course of action with respect to a specific principle or tenet one needs a certain amount of information about that course of action, information related to that principle or tenet. This information is obtained by asking a series of questions.

The answer to each question allows one to reduce the current assessment task to a more specific and simpler one.

This process continues until one has enough information to recognize a weakness or a strength.



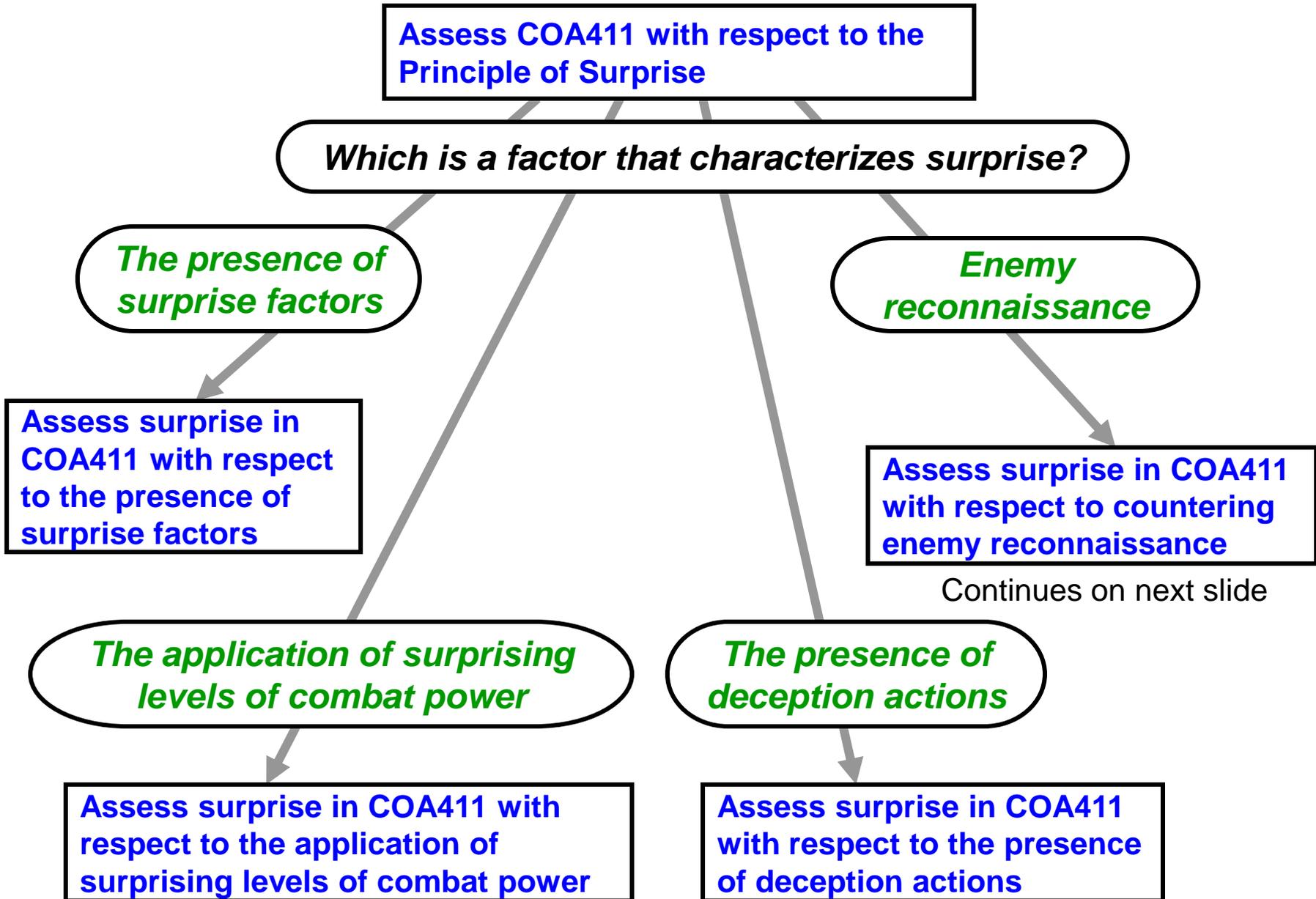
Each leaf is a solution (a weakness or a strength). The solution corresponding to an intermediate node is the union of the solutions of its immediate children.

The Principle of Surprise (from FM100-5)

Strike the enemy at a time or place or in a manner for which he is unprepared.

Surprise can decisively shift the balance of combat power. By seeking surprise, forces can achieve success well out of proportion to the effort expended. Rapid advances in surveillance technology and mass communication make it increasingly difficult to mask or cloak large-scale marshaling or movement of personnel and equipment. The enemy need not be taken completely by surprise but only become aware too late to react effectively. Factors contributing to surprise include speed, effective intelligence, deception, application of unexpected combat power, operations security (OPSEC), and variations in tactics and methods of operation. Surprise can be in tempo, size of force, direction or location of main effort, and timing. Deception can aid the probability of achieving surprise.

COA411 - Surprise



COA411 - Surprise

Continues from previous slide

**Assess surprise in COA411
with respect to countering
enemy reconnaissance**

Is an enemy reconnaissance unit present?

*Yes, RED-CSOP1 which is performing
the reconnaissance action SCREEN1*

No, ...

**Assess surprise in COA411 where the
enemy unit RED-CSOP1 performs the
reconnaissance action SCREEN1**

Continues on next slide

COA411 - Surprise

Assess surprise in COA411 where the enemy unit RED-CSOP1 performs the reconnaissance action SCREEN1

Is the enemy reconnaissance unit destroyed?

Yes, RED-CSOP1 is destroyed by DESTROY1

No, ...

ASSESSMENT: There is a strength with respect to surprise in COA411 because it contains aggressive security/counter-reconnaissance plans, destroying enemy intelligence collection units and activities. Intelligence collection by RED-CSOP1 through SCREEN1 will be disrupted by its destruction by DESTROY1. This and similar actions prevent the enemy for ascertaining the nature and intent of friendly operations, thereby increasing the likelihood that the enemy will be surprised. This is a strength of high importance.

REFERENCE: FM 100-5 pg 2-5, KF 118.1, KF 118.2, KF 118.3 - Surprise is achieved by striking/engaging the enemy in a time, place or manner for which he is unprepared. The enemy can be surprised by the tempo of the operation, the size of the force, the direction or location of the main effort, and timing. Factors contributing to surprise include speed, effective intelligence, deception, application of unexpected combat power, operations security, and variations in tactics and methods of operation.

The Principle of Mass (from FM100-5)

Mass the effects of overwhelming combat power at the decisive place and time.

Synchronizing all the elements of combat power where they will have decisive effect on an enemy force in a short period of time is to achieve mass. To mass is to hit the enemy with a closed fist, not poke at him with fingers of an open hand. Mass must also be sustained so the effects have staying power. Thus, mass seeks to smash the enemy, not sting him. This results from the proper combination of combat power with the proper application of other principles of war. Massing effects, rather than concentrating forces, can enable numerically inferior forces to achieve decisive results, while limiting exposure to enemy fire.

COA411 - Mass

I need to

Assess COA411 with respect to the Principle of Mass

Does COA411 identify a decisive point?

Yes, it identifies the decisive point RED-MECH-COMPANY4.

Therefore I need to

Assess mass for COA411 with RED-MECH-COMPANY4 as the decisive point

Does the main effort act on RED-MECH-COMPANY4 with an adequate force ratio?

Yes, it acts with a force ratio of 10.6

Therefore I need to

Assess mass for COA411 when the main effort acts on RED-MECH-COMPANY4 with the adequate force ratio of 10.6.

Does the main effort get help acting on RED-MECH-COMPANY4?

Yes, it gets help from the supporting action SUPPRESS1, which also acts on RED-MECH-COMPANY4.

Therefore I conclude that

There is a major strength in COA411 with respect to mass because BLUE-TASK-FORCE1 is the MAIN-EFFORT1 and it acts on the decisive point of the COA (RED-MECH-COMPANY4) with a force ratio of 10.6, which exceeds a recommended force ratio of 3.0. Additionally, the main effort is assisted by the supporting action SUPPRESS1 which also acts on the decisive point. This is good evidence of the allocation of significantly more than minimum combat power required at the decisive point and is indicative of the proper application of the principle of mass.

Sample Critiques Generated by the COA Agent

To what extent does this course of action conform to the Principle of Mass?



There is a major strength in COA411 with respect to mass because BLUE-TASK-FORCE1 is the MAIN-EFFORT1 and it acts on the decisive point of the COA (RED-MECH-COMPANY4) with a force ratio of 10.6, which exceeds a recommended force ratio of 3.0. Additionally, the main effort is assisted by supporting action SUPPRESS-MILITARY-TASK1 which also acts on the decisive point. This is good evidence of the allocation of significantly more than minimum combat power required at the decisive point and is indicative of the proper application of the principle of mass.

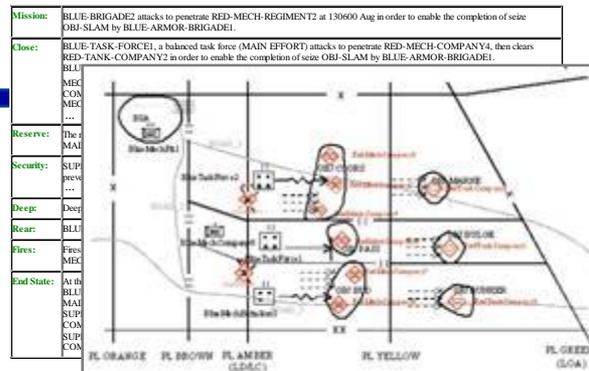
There is a strength in COA411 with respect to mass because BLUE-TASK-FORCE1 is the main effort of the COA and it has been allocated 33% of available combat power but this is considered just a medium level weighting of the main effort.

Reference: FM 100-5 pg 2-4, KF 113.1, KF 113.2, KF 113.3, KF 113.4, KF 113.5 - To mass is to synchronize the effects of all elements of combat power at the proper point and time to achieve decisive results. Observance of the Principle of Mass may be evidenced by allocation to the main effort of significantly greater combat power than the minimum required throughout its mission, accounting for expected losses. Mass is evidenced by the allocation of significantly more than minimum combat power required at the decisive point.

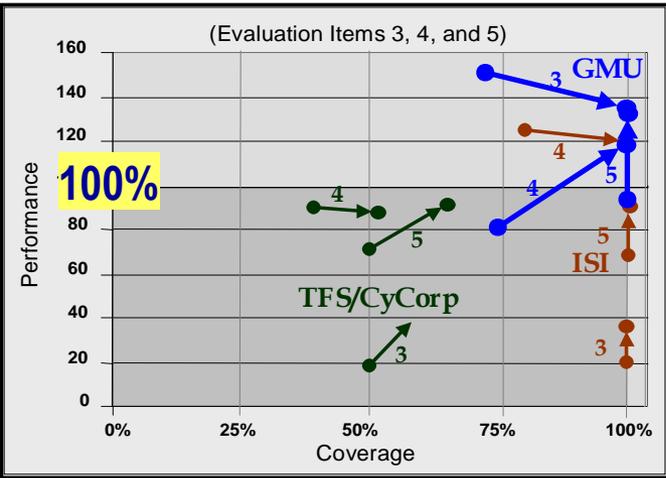
There is a strength in COA411 with respect to mass because BLUE-MECH-COMPANY8 is a COMPANY-UNIT-DESIGNATION level maneuver unit assigned to be the reserve. This is considered a strong reserve for a BRIGADE-UNIT-DESIGNATION level COA and would be available to continue the operation or exploit success.

Evaluation of COA Agents (DARPA)

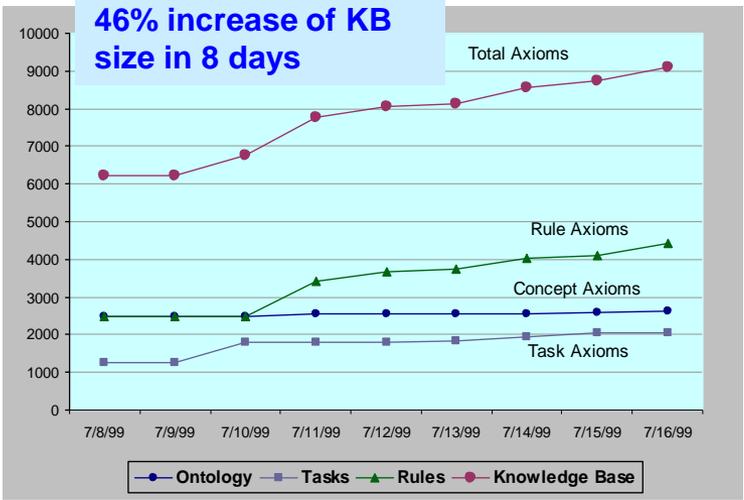
Disciple-COA: Identifies strengths and weaknesses in a Course of Action, based on the principles of war and the tenets of army operations.



Disciple-COA demonstrated the generality of its learning methods that used an object ontology created by another group (TFS/CyCorp). It also demonstrated that a knowledge engineer and a subject matter expert can jointly teach Disciple.



Evolution of KB coverage and performance from the pre-repair phase to the post-repair phase for the final 3 evaluation items.



Development of Disciple's KB during evaluation.

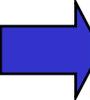
- Disciple-COA features:
- High knowledge acquisition rate;
 - Better performance than the other evaluated systems;
 - Better performance than the evaluating experts (many unanticipated solutions).

Overview

Knowledge Base Organization

Reasoning Mechanisms

Disciple-COA: Critiquing as Expertise Problem

 **Disciple-WA: Workaround as Expertise Problem**

Reading

Planning As an Expertise Task

Planning means developing a sequence of actions that achieve a desired goal.

Examples:

Develop a plan for a military unit to reconstitute or bypass damage to a transportation infrastructure, such as a damaged bridge, a tunnel or a road.

Develop a plan of how to manufacture a loudspeaker.

Develop a plan of how to travel from one location to another.

Workaround Planning

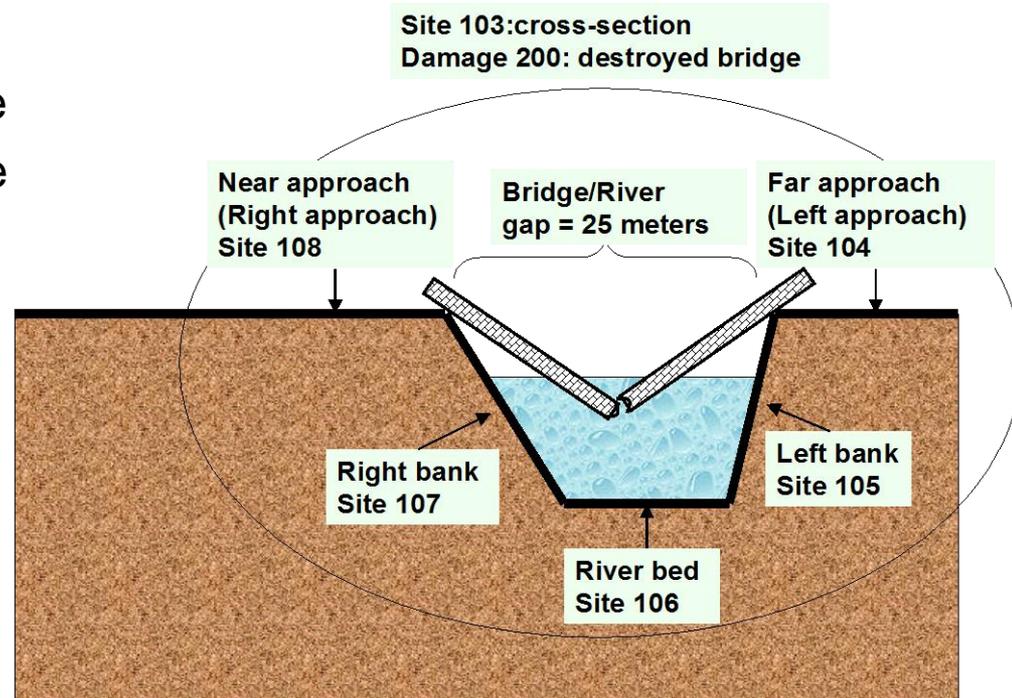
Estimate enemy's best way of working around damage to a transportation infrastructure, such as a damaged bridge or a cratered road.

Input problem

- description of a military unit that needs to work around some damage
- description of the damage and of the terrain
- description of the resources in the area that could be used to repair the damage

Solution

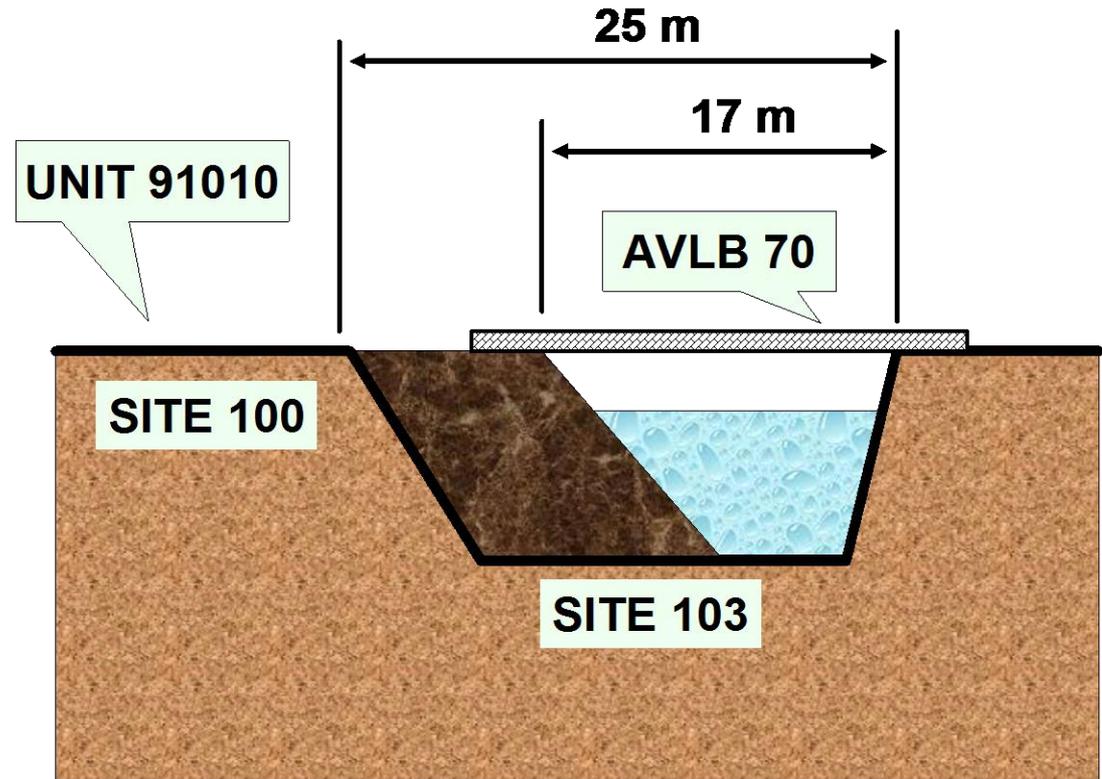
- detailed plan of actions
- minimum duration
- expected duration
- resources
- link capacity



Sample Workaround Problem and Solution

Workaround solution
for a destroyed
bridge on larger river:

Narrow gap and
install AVLB



Workaround summary

Initial task:

WORKAROUND-DAMAGE
FOR-DAMAGE DAMAGE200
BY-INTERDICTED-UNIT UNIT91010

Engineering action: INSTALL AVLB

MIN-DURATION 11H:4M:58S
EXPECTED-DURATION 14H:25M:56S
RESOURCES REQUIRED (AVLB-UNIT202 BULLDOZER-UNIT201)
LINK CAPACITY AFTER RECONSTRUCTION 2.2521622 VEHIC/MIN

S1 OBTAIN-OPERATIONAL-CONTROL-FROM-CORPS
OF-UNIT UNIT202
BY-UNIT UNIT91010
MIN-DURATION 4H:0M:0S
EXPECTED-DURATION 6H:0M:0S
TIME-CONSTRAINTS: NONE

S2 MOVE-UNIT
FOR-UNIT UNIT202
FROM-LOCATION SITE0
TO-LOCATION SITE100
MIN-DURATION 1H:8M:14S
EXPECTED-DURATION 1H:8M:14S
TIME-CONSTRAINTS: AFTER S1

S3 REPORT-OBTAINED-EQUIPMENT
FOR-EQ-SET AVLB-UNIT202
MIN-DURATION 0S
EXPECTED-DURATION 0S
TIME-CONSTRAINTS: AFTER S2

S4 OBTAIN-OPERATIONAL-CONTROL-FROM-CORPS
OF-UNIT UNIT201
BY-UNIT UNIT91010
MIN-DURATION 4H:0M:0S
EXPECTED-DURATION 6H:0M:0S
TIME-CONSTRAINTS: NONE

S5 MOVE-UNIT
FOR-UNIT UNIT201
FROM-LOCATION SITE0
TO-LOCATION SITE100
MIN-DURATION 1H:8M:14S
EXPECTED-DURATION 1H:8M:14S
TIME-CONSTRAINTS: AFTER S4

S6 REPORT-OBTAINED-EQUIPMENT
FOR-EQ-SET BULLDOZER-UNIT201
MIN-DURATION 0S
EXPECTED-DURATION 0S
TIME-CONSTRAINTS: AFTER S5

S7 NARROW-GAP-BY-FILLING-WITH-BANK
FOR-GAP SITE103
FOR-BR-DESIGN AVLB70
MIN-DURATION 5H:19M:44S
EXPECTED-DURATION 6H:7M:42S
RESOURCES-REQUIRED BULLDOZER-UNIT201
TIME-CONSTRAINTS: AFTER S6

S8 EMPLACE-AVLB
FOR-BR-DESIGN AVLB70
MIN-DURATION 5M:0S
EXPECTED-DURATION 10M:0S
RESOURCES-REQUIRED AVLB-UNIT202
TIME-CONSTRAINTS: AFTER S3, S7

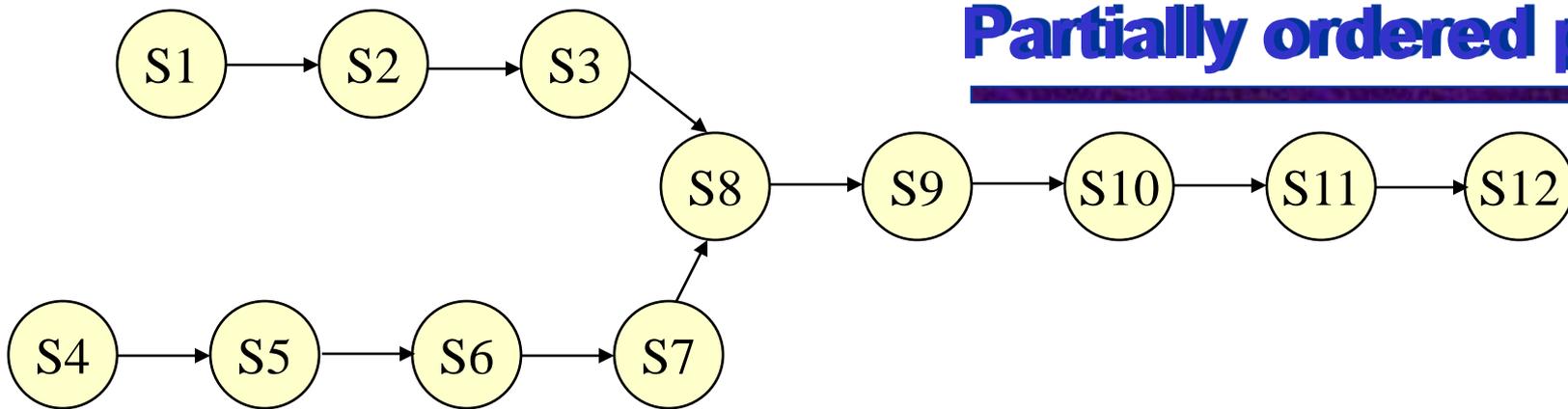
S9 REPORT-EMPLACED-FIXED-BRIDGE
FOR-MIL-BRIDGE IXED-MILITARY-BRIDGE-EQ
MIN-DURATION 0S
EXPECTED-DURATION 0S
TIME-CONSTRAINTS: AFTER S8

S10 MOVE-EQUIPMENT-OVER-UNSTABILIZED-MIL-BRIDGE
FOR-EQ-SET BULLDOZER-UNIT201
FOR-BR-DESIGN AVLB70
MIN-DURATION 2M:0S
EXPECTED-DURATION 10M:0S
RESOURCES-REQUIRED AVLB-UNIT202
TIME-CONSTRAINTS: AFTER S9

S11 MINOR-BANK-PREPARATION
OF-BANK SITE105
MIN-DURATION 30M:0S
EXPECTED-DURATION 50M:0S
RESOURCES-REQUIRED BULLDOZER-UNIT201
TIME-CONSTRAINTS: AFTER S10

S12 RESTORE-TRAFFIC-LINK
FOR-UNIT UNIT91010
FOR-LINK AVLB70
LINK-CAPACITY 2.2521622 VEHICLES/MIN
MIN-DURATION 0S
EXPECTED-DURATION 0S
TIME-CONSTRAINTS: AFTER S11

Partially ordered plan



S1 OBTAIN-OPERATIONAL-CONTROL-FROM-CORPS
 OF-UNIT UNIT202
 BY-UNIT UNIT91010

S2 MOVE-UNIT
 FOR-UNIT UNIT202
 FROM-LOCATION SITE0
 TO-LOCATION SITE100
 TIME-CONSTRAINTS: AFTER S1

S3 REPORT-OBTAINED-EQUIPMENT
 FOR-EQ-SET AVLB-UNIT202
 TIME-CONSTRAINTS: AFTER S2

S4 OBTAIN-OPERATIONAL-CONTROL-FROM-CORPS
 OF-UNIT UNIT201
 BY-UNIT UNIT91010

S5 MOVE-UNIT
 FOR-UNIT UNIT201
 FROM-LOCATION SITE0
 TO-LOCATION SITE100
 TIME-CONSTRAINTS: AFTER S4

S6 REPORT-OBTAINED-EQUIPMENT
 FOR-EQ-SET BULLDOZER-UNIT201
 TIME-CONSTRAINTS: AFTER S5

S7 NARROW-GAP-BY-FILLING-WITH-BANK
 FOR-GAP SITE103
 FOR-BR-DESIGN AVLB70
 TIME-CONSTRAINTS: AFTER S6

S8 EMPLACE-AVLB
 FOR-BR-DESIGN AVLB70
 TIME-CONSTRAINTS: AFTER S3, S7

S9 REPORT-EMPLACED-FIXED-BRIDGE
 FOR-MIL-BRIDGE FIXED-MILITARY-BRIDGE-EQ
 TIME-CONSTRAINTS: AFTER S8

S10 MOVE-EQUIPMENT-OVER-UNSTABILIZED-MIL-BRIDGE
 FOR-EQ-SET BULLDOZER-UNIT201
 FOR-BR-DESIGN AVLB70
 TIME-CONSTRAINTS: AFTER S9

S11 MINOR-BANK-PREPARATION
 OF-BANK SITE105
 MIN-DURATION 30M:0S
 TIME-CONSTRAINTS: AFTER S10

S12 RESTORE-TRAFFIC-LINK
 FOR-UNIT UNIT91010
 FOR-LINK AVLB70
 LINK-CAPACITY 2.2521622 VEHICLES/MIN
 TIME-CONSTRAINTS: AFTER S11

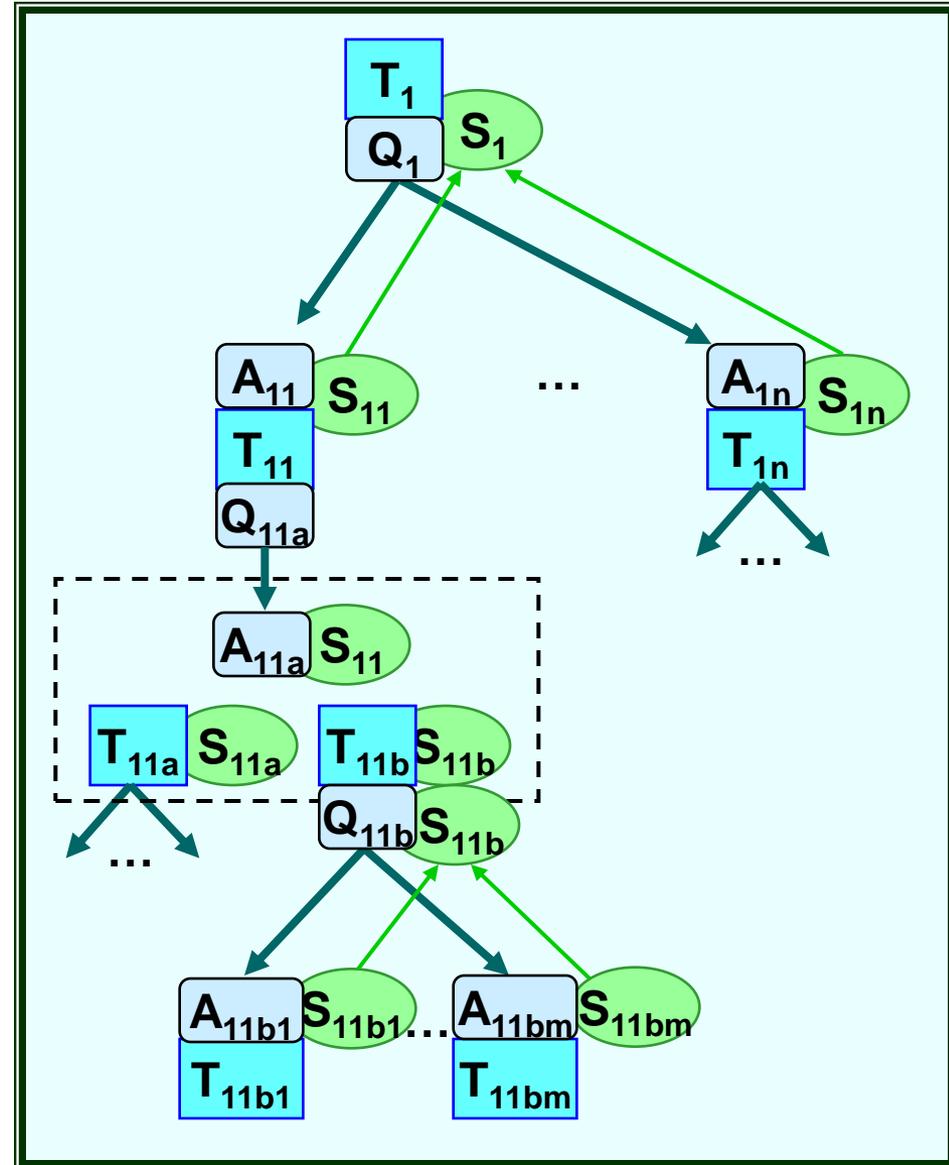
Planning through task reduction

T_1 is a general action/task that accomplishes the goal.

Ask a question about the current situation to determine alternative ways of performing this action. If the answer of Q_1 is A_{11} , then to perform T_1 one could perform T_{11} .

When the action to perform (e.g. T_{11}) is completely defined, break it down into sub-actions (e.g. T_{11a} and T_{11b}). In this case the question and the answer summarize the solution, or could simply be absent.

Continue this reduction process until you obtain elementary actions.



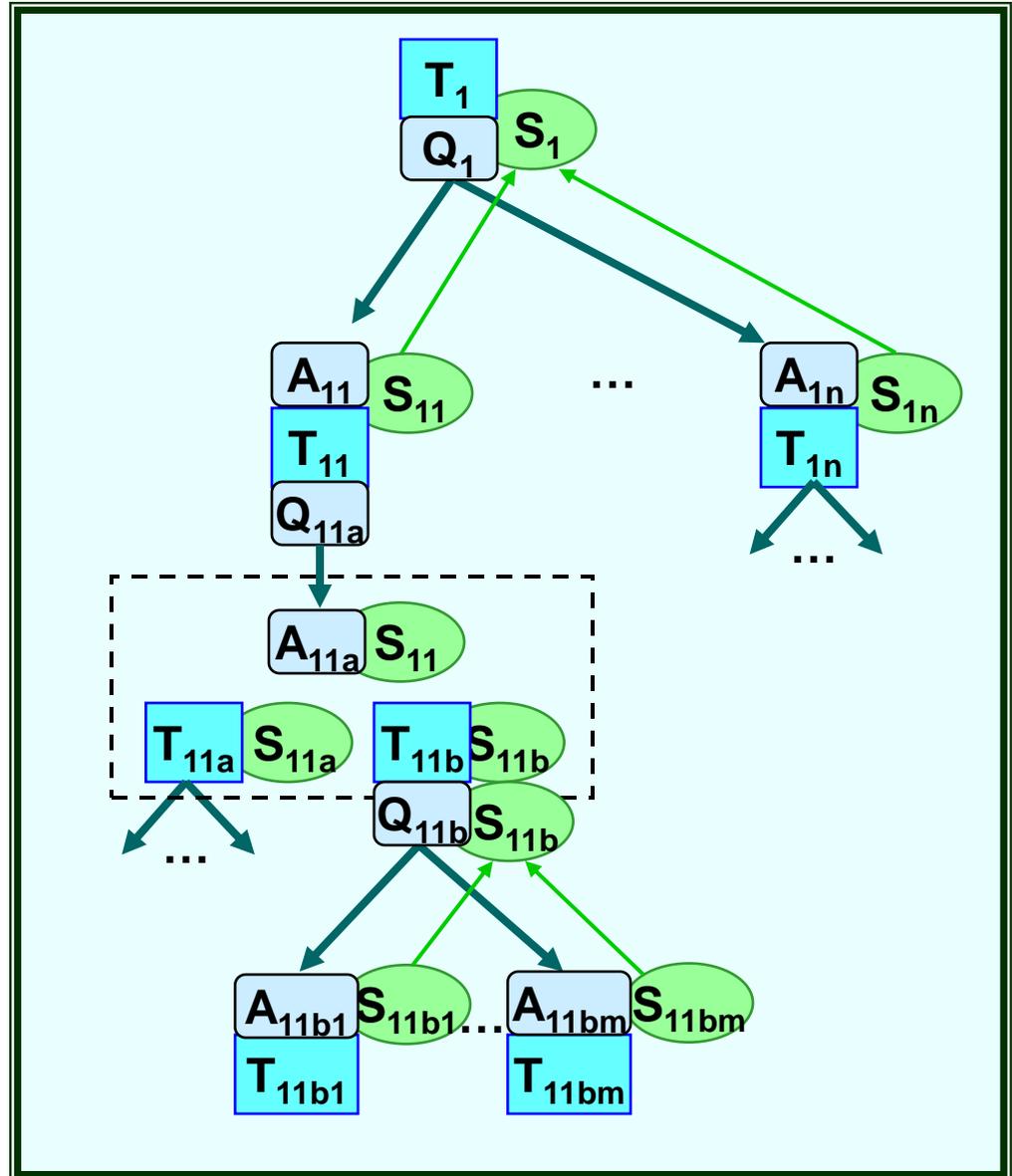
Planning through task reduction (cont.)

Follow the tree from bottom to top to compose the elementary actions into plans, as follows:

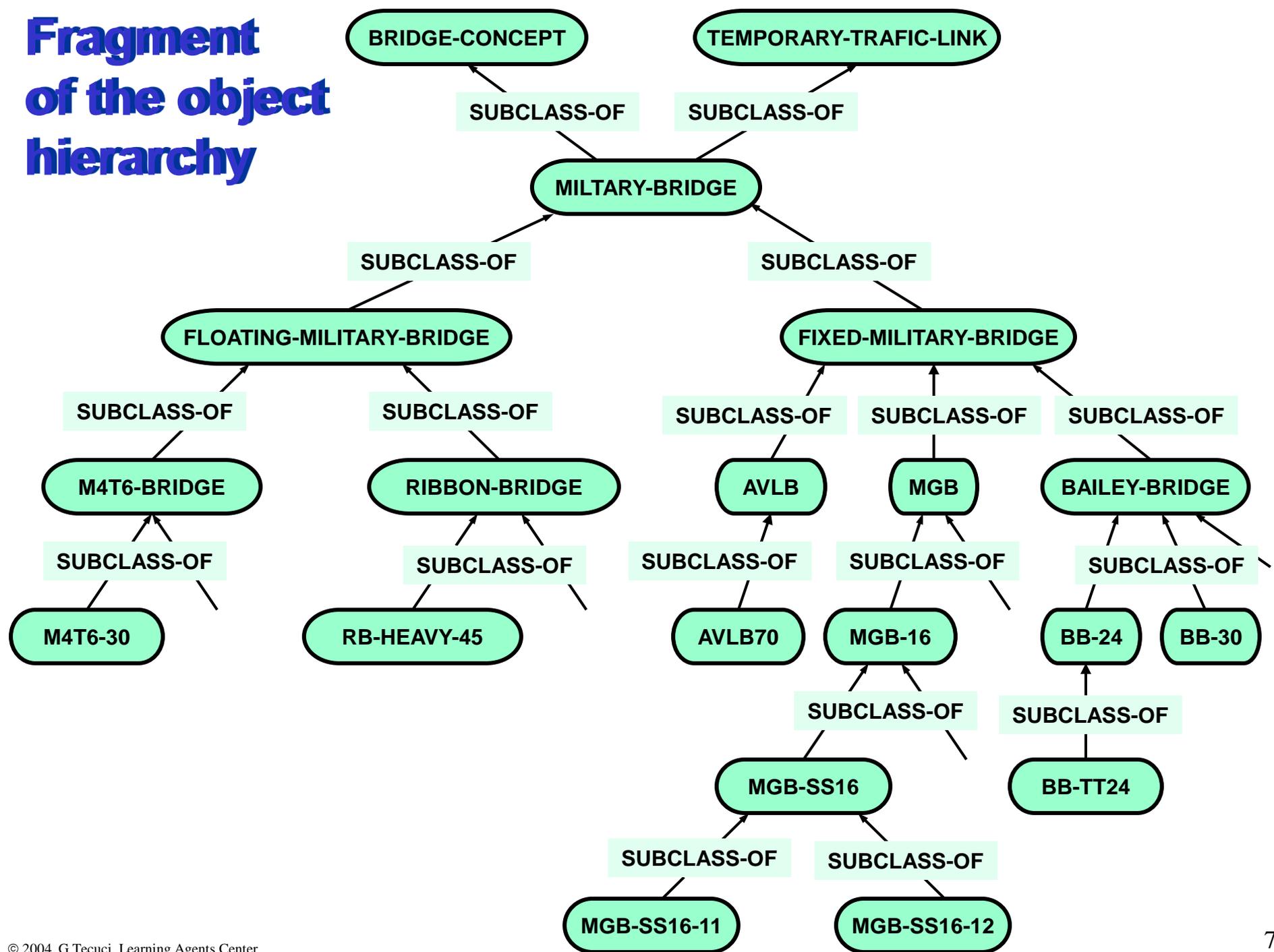
S_{11b} is the union of $S_{11b1} \dots S_{11bm}$

This leads to alternative plans.

S_{11} is the set of plans obtained by composing the sub-plans from S_{11a} and the sub-plans from S_{11b} .



Fragment of the object hierarchy

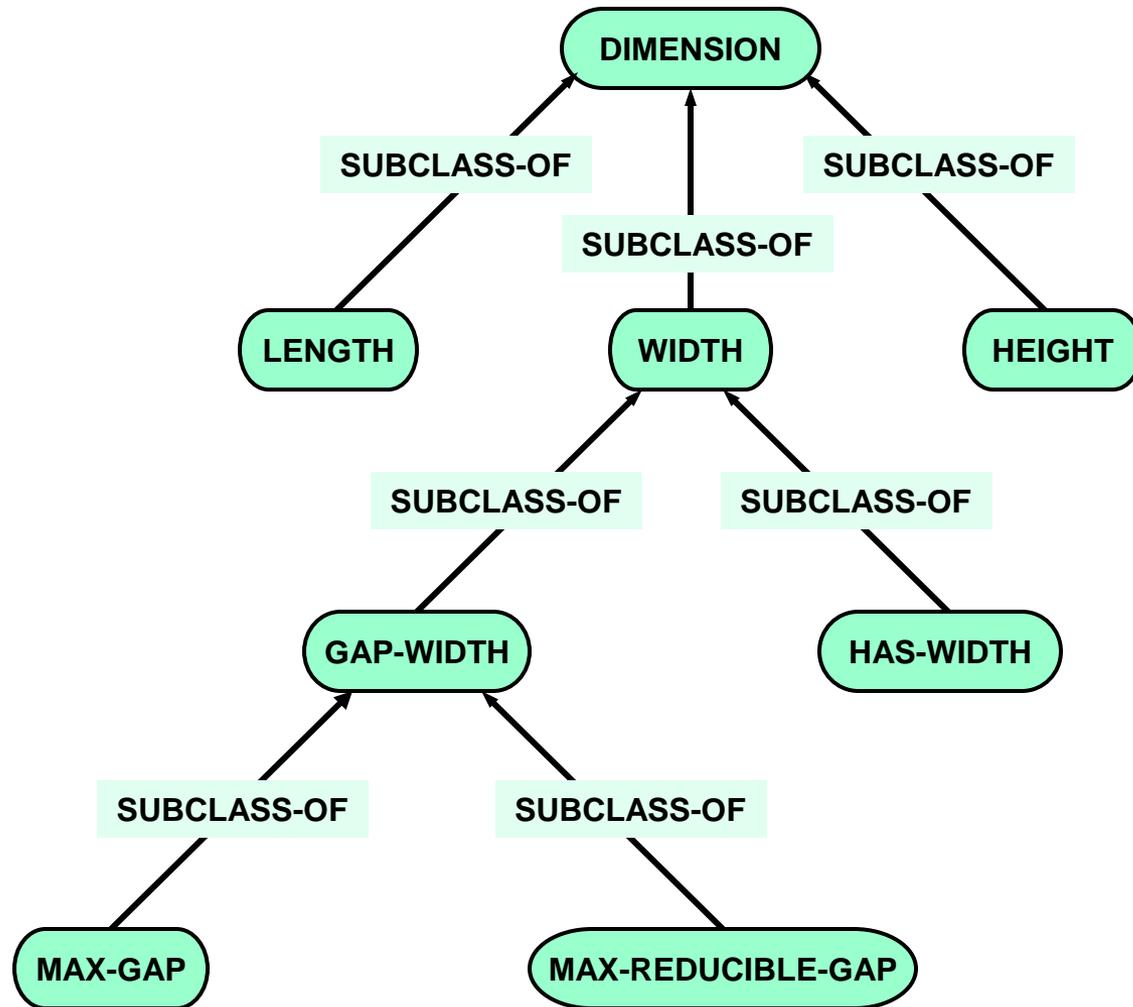


Sample object descriptions

AVLB	subclass-of	FIXED-MILITARY-BRIDGE
	expected-crossing-time-for-unstabilized-end	10 min
	expected-emplacement-time	10 min
	max-downhill-slope-for-eq	19 %
	max-transverse-slope	11 %
	max-uphill-slope-for-eq	28 %
	min-crossing-time-for-unstabilized-end	2 min
	min-emplacement-time	5 min

AVLB70	subclass-of	AVLB
	has-length	19.2 meters
	max-gap	17 meters
	max-reducible-gap	26 meters
	mlc-rating	70 tons
	weight-in-tons	15 tons

Fragment of the feature hierarchy



Task reduction rule

IF the task to accomplish is

WORKAROUND-UNMINED-DESTROYED-BRIDGE-WITH-FIXED-BRIDGE

AT-LOCATION ?O1
FOR-GAP ?O2
BY-UNIT ?O3

Plausible upper bound

?O1 IS BRIDGE
?O2 IS CROSS-SECTION
HAS-WIDTH ?N4
?O3 IS MILITARY-UNIT
MAX-TRACKED-MLC ?N3
MAX-WHEELED-MLC ?N2
?O4 IS AVLB-EQ
CAN-BUILD ?O5
MAX-REDUCIBLE-GAP ?N5
MAX-GAP ?N6
?O5 IS AVLB70
MLC-RATING ?N1
?N1 IS-IN [0.0 150.0]
?N2 IS-IN [0.0 150.0]
≤ ?N1
?N3 IS-IN [0.0 150.0]
≤ ?N1
?N4 IS-IN [0.0 100.0]
?N5 IS-IN [0.0 100.0]
≥ ?N4
?N6 IS-IN [0.0 100.0]
< ?N4

Plausible lower bound

?O1 IS SITE100
?O2 IS SITE103
HAS-WIDTH ?N4
?O3 IS UNIT91010
MAX-TRACKED-MLC ?N3
MAX-WHEELED-MLC ?N2
?O4 IS AVLB-EQ
CAN-BUILD ?O5
MAX-REDUCIBLE-GAP ?N5
MAX-GAP ?N6
?O5 IS AVLB70
MLC-RATING ?N1
?N1 IS-IN [70.0 70.0]
?N2 IS-IN [25.0 25.0]
≤ ?N1
?N3 IS-IN [63.0 63.0]
≤ ?N1
?N4 IS-IN [25.0 25.0]
?N5 IS-IN [26.0 26.0]
≥ ?N4
?N6 IS-IN [17.0 17.0]
< ?N4

THEN accomplish the task

USE-FIXED-BRIDGE-WITH-GAP-REDUCTION-OVER-GAP

AT-LOCATION ?O1
FOR-GAP ?O2
BY-UNIT ?O3
WITH-BR-EQ ?O4

Sample Workaround Problem: Mined Bridge

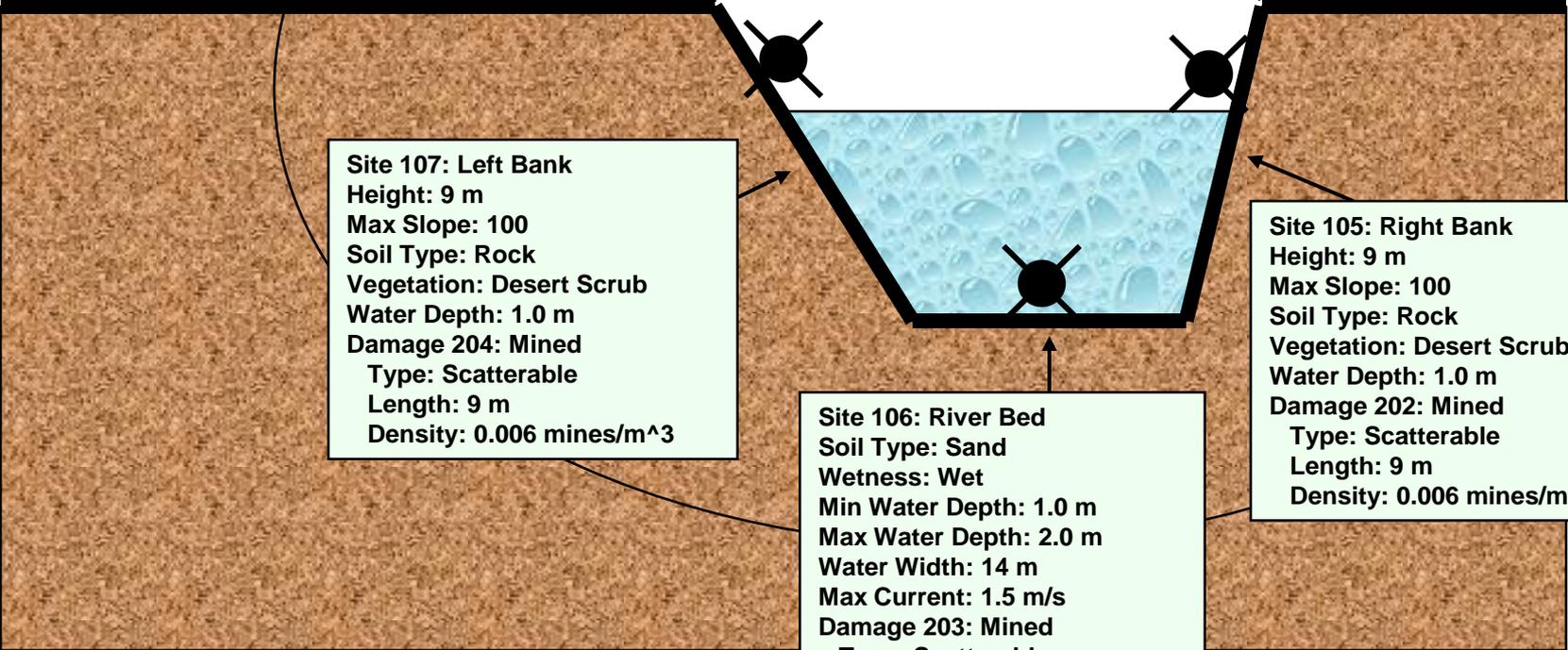
Detailed sketch Damage Bridge at Site 100

Site 103: Cross-Section
 Damage 200: Mined Bridge
 Type: Scatterable
 Length: 30 m
 Density: 0.006 mines/m³

Site 108: Near Approach
 (Left Approach)
 Damage 205: Mined
 Type: Scatterable
 Length: 400 m
 Density: 0.006 mines/m³

Bridge/River
 Width: 30 m

Site 104: Far Approach
 (Right Approach)
 Damage 201: Mined
 Type: Scatterable
 Length: 200 m
 Density: 0.006 mines/m³



Site 107: Left Bank
 Height: 9 m
 Max Slope: 100
 Soil Type: Rock
 Vegetation: Desert Scrub
 Water Depth: 1.0 m
 Damage 204: Mined
 Type: Scatterable
 Length: 9 m
 Density: 0.006 mines/m³

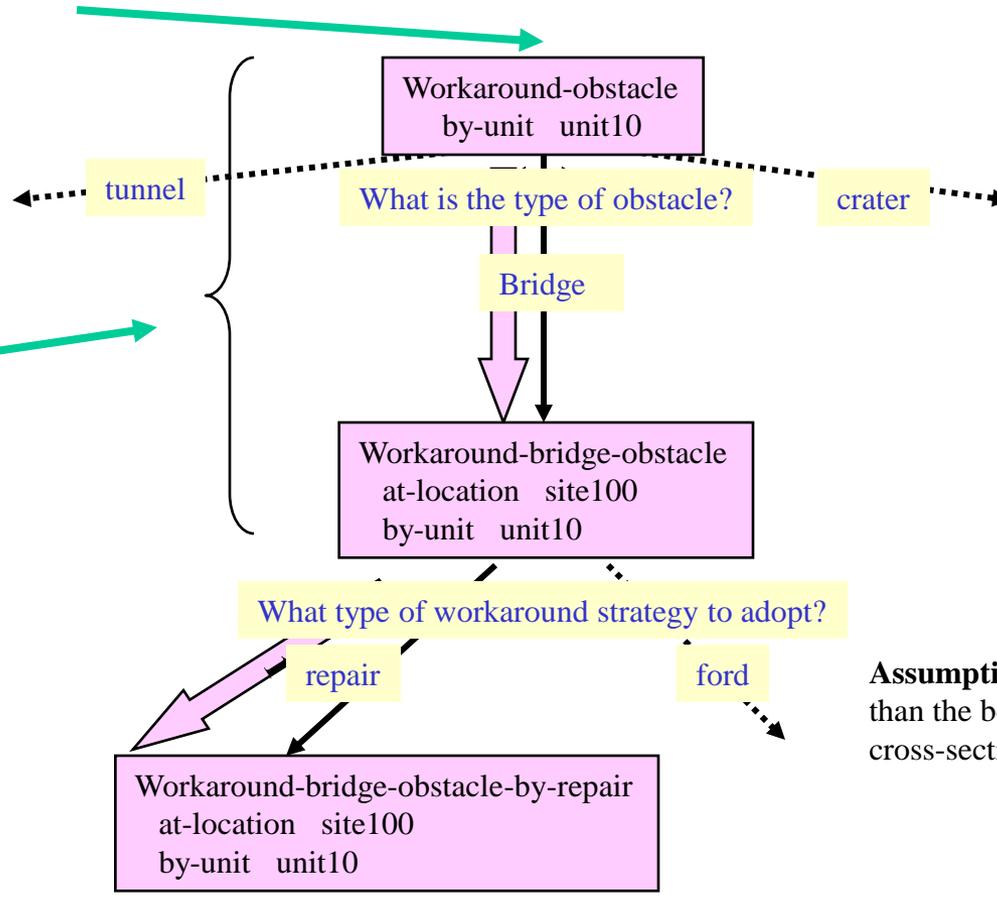
Site 105: Right Bank
 Height: 9 m
 Max Slope: 100
 Soil Type: Rock
 Vegetation: Desert Scrub
 Water Depth: 1.0 m
 Damage 202: Mined
 Type: Scatterable
 Length: 9 m
 Density: 0.006 mines/m³

Site 106: River Bed
 Soil Type: Sand
 Wetness: Wet
 Min Water Depth: 1.0 m
 Max Water Depth: 2.0 m
 Water Width: 14 m
 Max Current: 1.5 m/s
 Damage 203: Mined
 Type: Scatterable
 Length: 12 m
 Density: 0.006 mines/m³

1

A general action that accomplishes the goal.

Reduce a task to a simpler task



Assumption: if a bridge is mined than the bed of the corresponding cross-section is mined.

2

Non-elementary task

Elementary task

Reduce a task to two simpler sub-tasks

Workaround-bridge-obstacle-by-repair
at-location site100
by-unit unit10

How to workaround the bridge by repair?

Repair the bridge and restore the traffic link.

Repair-bridge
at-location site100
by-unit unit10

Restore-traffic-link-to-original-capacity
for-unit unit10
for-link site100
min-duration 0 min
expected-duration 0 min

What is the type of damage to the bridge?

Damage200 consists only of mines

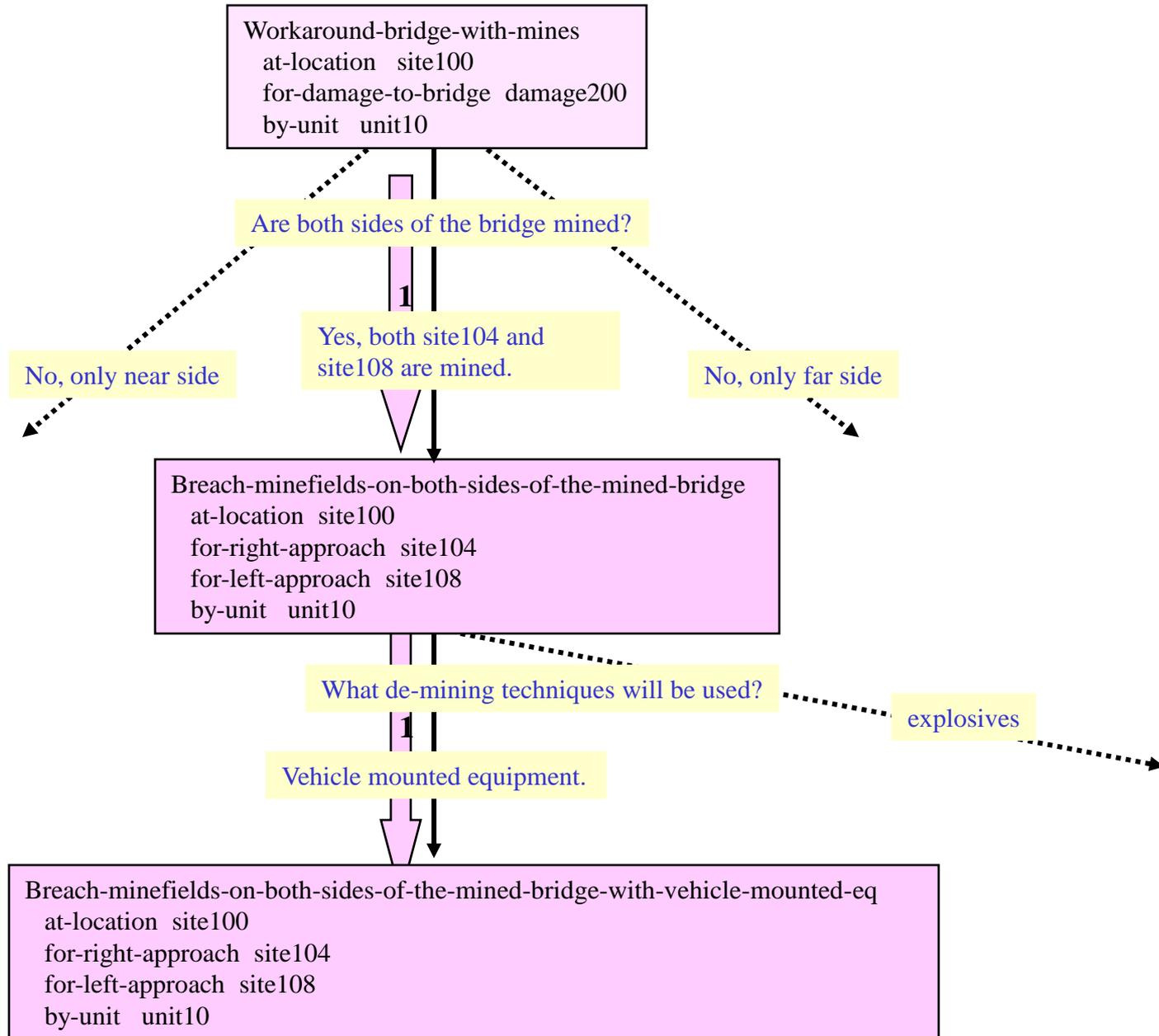
Damaged bridge but no mines

Mined and damaged bridge

Workaround-bridge-with-mines
at-location site100
for-damage-to-bridge damage200
by-unit unit10

3

3



4

4

Breach-minefields-on-both-sides-of-the-mined-bridge-with-vehicle-mounted-eq
at-location site100
for-right-approach site104
for-left-approach site108
by-unit unit10

Is vehicle mounted equipment available in the unit?

Yes, Tank-with-plow-Unit101

Breach-minefields-on-both sides-of-the-mined-bridge-with-own-vehicle-mounted-eq
at-location site100
for-right-approach site104
for-left-approach site108
with-mounted-vehicle-lane-clearing-eq-set Tank-with-plow-Unit101
by-unit unit10

5

5

Breach-minefields-on-both sides-of-the-mined-bridge-with-own-vehicle-mounted-eq
 at-location site100
 for-right-approach site104
 for-left-approach site108
 with-mounted-vehicle-lane-clearing-eq-set Tank-with-plow-Unit101
 by-unit unit10

How to perform this breaching?

By breaching the near approach, then the bridge and then the far approach.

1

Breach-minefields-on-near approach and bank-with-vehicle-mounted-eq
 for-approach site108
 for-bank site107
 with-mounted-vehicle-lane-clearing-eq-set Tank-with-plow-Unit101
 by-unit unit10

6

Report-near approach and bank cleared of mines
 for-approach site108
 for-bank site107

Remove-mines-on-bridge-using-mine-plow-p
 at-location site100
 with-mounted-vehicle-lane-clearing-eq-set Tank-with-plow-Unit101
 by-unit unit10

9

Report-bridge-cleared-of-mines
 for-bridge site100

Breach-minefields-on-far-approach-and-bank vehicle-mounted-eq
 for-approach site104
 for-bank site105
 with-mounted-vehicle-lane-clearing-eq-set Tank-with-plow-Unit101
 by-unit unit10

10

Report-far approach and bank cleared of mines
 for-approach site104
 for-bank site105

6

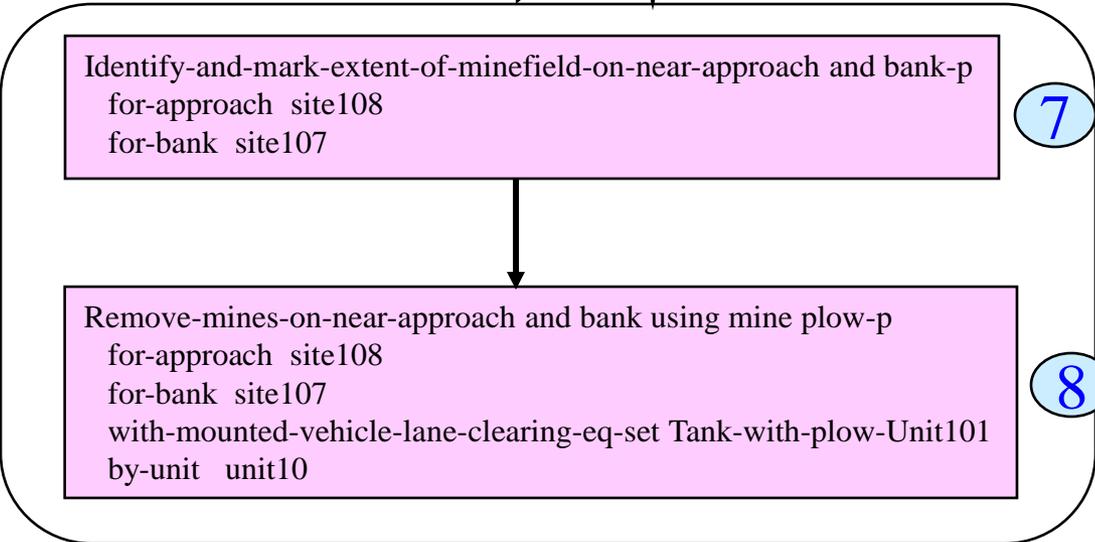
Breach-minefields-on-near approach and bank-with-vehicle-mounted-eq
for-approach site108
for-bank site107
with-mounted-vehicle-lane-clearing-eq-set Tank-with-plow-Unit101
by-unit unit10

Is mine clearing equipment mounted and ready for use?

No, mine clearing equipment must be mounted.

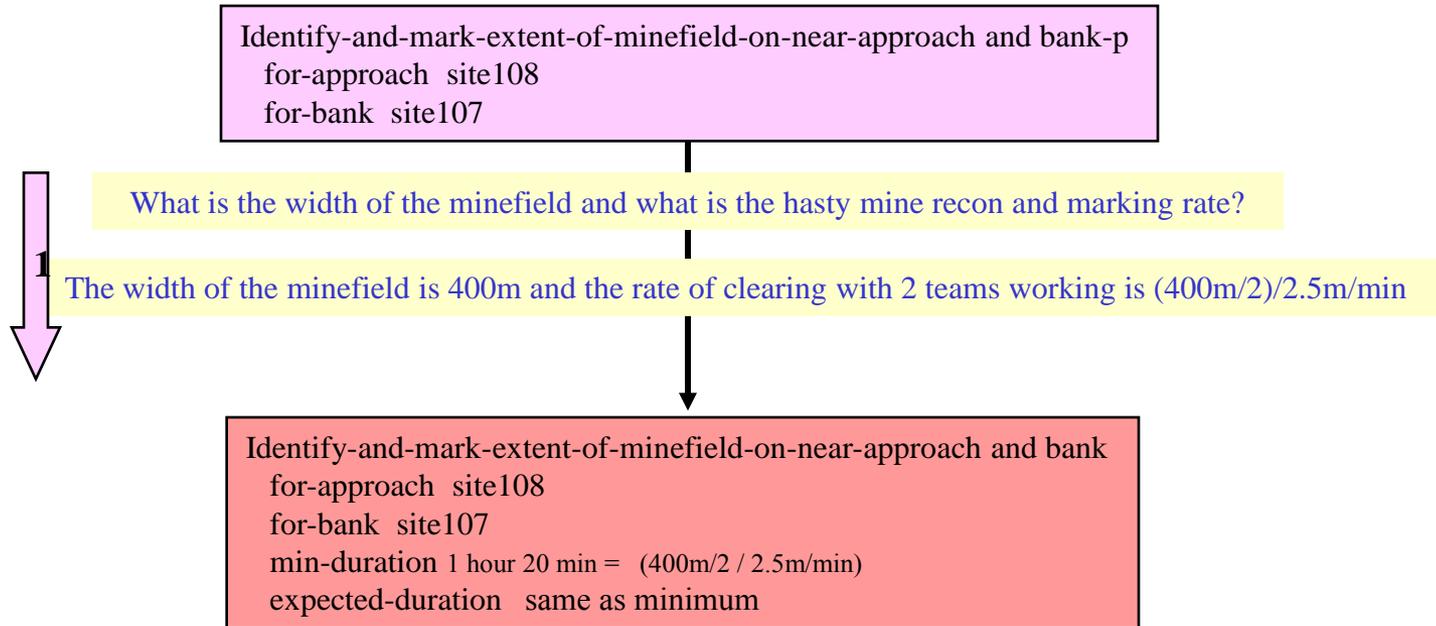
Yes, Tank-with-plow-Unit 101 is ready.

1



7

8



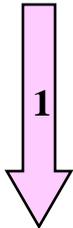
Remove-mines-on-near-approach and bank using mine plow-p
 for-approach site108
 for-bank site107
 with-mounted-vehicle-lane-clearing-eq-set Tank-with-plow-Unit101
 by-unit unit10

What is the depth of the minefield and what is the mineplow clearing rate?

The length of the minefield is 400m, the minimum rate of mineplow clearing is 0.05min/m and the expected rate is 0.1min/m

Remove-mines-on-near-approach and bank using mine plow
 for-approach site108
 for-bank site107
 min-duration $(400 \text{ m} * 0.05\text{min/m} + 5 \text{ min}) = 25 \text{ min}$
 expected-duration $(400 \text{ m} * 0.1\text{min/m} + 10 \text{ min}) = 50 \text{ min}$
 resources Tank-with-plow-Unit101

Remove-mines-on-bridge-using-mine-plow-p
 at-location site100
 with-mounted-vehicle-lane-clearing-eq-set Tank-with-plow-Unit101
 by-unit unit10



What is the depth of the minefield and what is the mineplow clearing rate?

The min bridge minefield width is 100m,
 the minimum rate of mine plow clearing is 0.05min/m
 and the expected rate is 0.1min/m
 add 5 min min prep time and 10 min expected prep time

Remove-mines-on-bridge- using mine plow
 for-bridge site100
 min-duration $(100 \text{ m} * 0.05\text{min/m}) + 5 \text{ min prep} = 10 \text{ min}$
 expected-duration $(100 \text{ m} * 0.1\text{min/m}) + 10 \text{ exp prep} = 20 \text{ min}$
 resources Tank-with-plow-Unit101

10

Breach-minefields-on-far approach and bank-with-vehicle-mounted-eq
for-approach site104
for-bank site105
with-mounted-vehicle-lane-clearing-eq-set Tank-with-plow-Unit101
by-unit unit10

How to breach the minefield on the far approach?

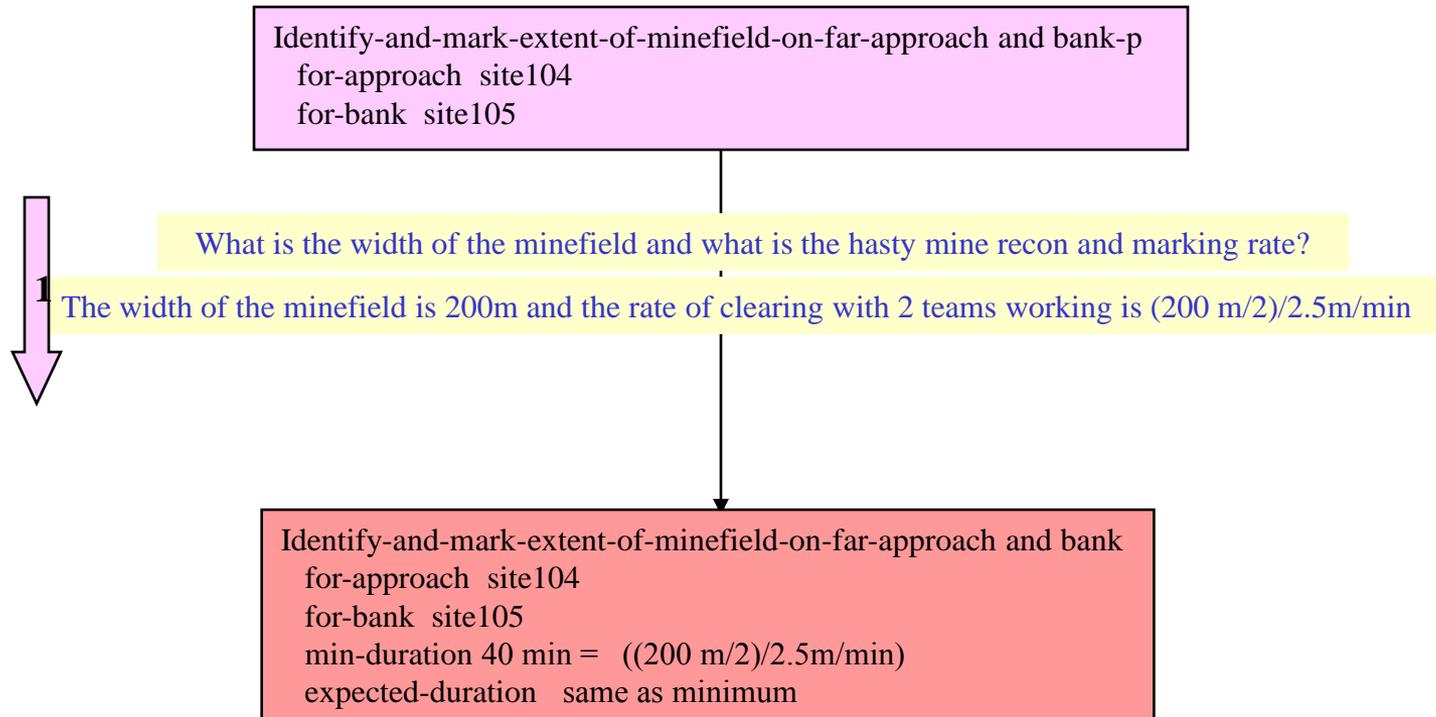
By first identifying and marking the mines and then removing them.

Identify-and-mark-extent-of-minefield-on-far-approach and bank-p
for-approach site104
for-bank site105

11

Remove-mines-on-far-approach and bank using mine plow-p
for-approach site104
for-bank site105
with-mounted-vehicle-lane-clearing-eq-set Tank-with-plow-Unit101
by-unit unit10

12

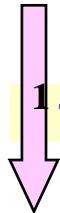


Remove-mines-on-far-approach and bank using mine plow-p
 for-approach site108
 for-bank site107
 with-mounted-vehicle-lane-clearing-eq-set Tank-with-plow-Unit101
 by-unit unit10

What is the depth of the minefield and what is the mineplow clearing rate?

The depth of the minefield is 250m, the minimum rate of mineplow clearing is 0.05min/m and the expected rate is 0.1min/m

Remove-mines-on-far-approach and bank using mine plow
 for-approach site104
 for-bank site105
 min-duration $(200 \text{ m} * 0.05\text{min/m}) + 5\text{min} = 15 \text{ min}$
 expected-duration $(200 \text{ m} * 0.1\text{min/m}) + 10\text{min} = 30 \text{ min}$
 resources Tank-with-plow-Unit101



The developed plan

Identify-and-mark-extent-of-minefield-on-near-approach-and-bank
for-approach site108
for-bank site107
min-duration 1 hour 20 min
expected-duration 1 hour 20 min

Remove-mines-on-near-approach-and-bank-using-mine-plow
for-approach site108
for-bank site107
min-duration 25 min
expected-duration 50 min
resources Tank-with-plow-Unit101

Report-near-approach-and-bank-cleared-of-mines
for-approach site108
for-bank site107
min-duration 0 min
expected-duration 0 min

Remove-mines-on-bridge-using-mine-plow
for-bridge site100
min-duration 10 min
expected-duration 20 min
resources Tank-with-plow-Unit101

Report-bridge-cleared-of-mines
for-bridge site100
min-duration 0 min
expected-duration 0 min

Identify-and-mark-extent-of-minefield-on-far-approach-and-bank
for-approach site104
for-bank site105
min-duration 40 min
expected-duration 40 min

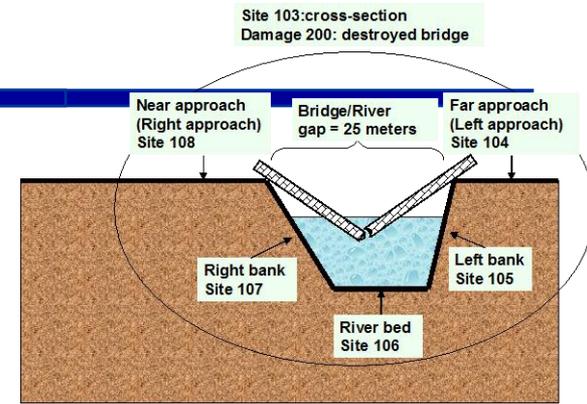
Remove-mines-on-far-approach-and-bank-using-mine-plow
for-approach site104
for-bank site105
min-duration 15 min
expected-duration 30 min
resources Tank-with-plow-Unit101

Report-far-approach-and-bank-cleared-of-mines
for-approach site104
for-bank site105
min-duration 0 min
expected-duration 0 min

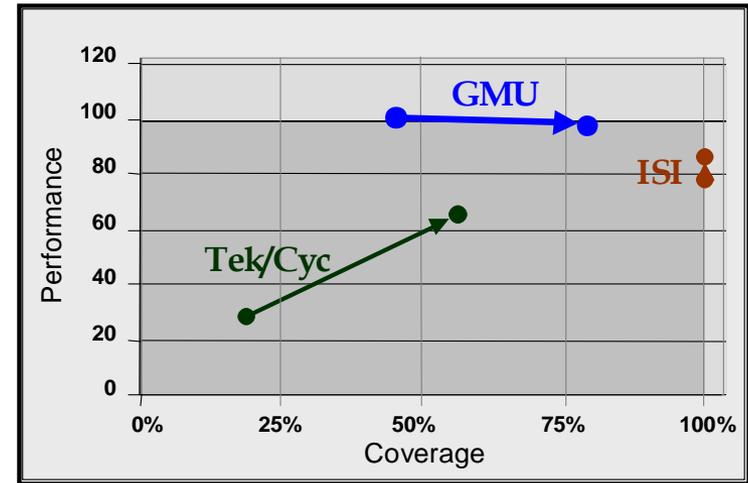
Restore-traffic-link-to-original-capacity
for-unit unit10
for-link site100
min-duration 0 min
expected-duration 0 min

Evaluation of Workaround Planners

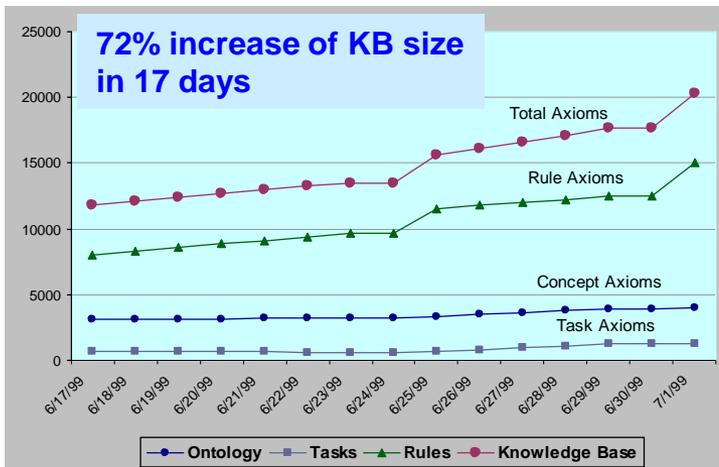
Disciple-WA: Estimates the best plan of working around damage to a transportation infrastructure, such as a damaged bridge or road.



Disciple-WA demonstrated that a knowledge engineer can use Disciple to rapidly build and update a knowledge base capturing knowledge from military engineering manuals and a set of sample solutions provided by a subject matter expert.



Evolution of KB coverage and performance from the pre-repair phase to the post-repair phase.



Development of Disciple's KB during evaluation.

Disciple-WA features:

- High knowledge acquisition rate;
- High problem solving performance (including unanticipated solutions).
- Demonstrated at EFX'98 as part of an integrated application led by Alphatech.

Reading

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

Gheorghe Tecuci, Mihai Boicu, Michael Bowman, and Dorin Marcu, with a preface by Murry Burke: "An Innovative Application from the DARPA Knowledge Bases Programs: Rapid Development of a Course of Action Critiquer," in *AI Magazine*, 22, 2, 2001, pp. 43-61. AAAI Press, Menlo Park, California, 2001.
http://lac.gmu.edu/publications/2001/TecuciG_Disciple_COA_IAAI.pdf
(recommended).

Tecuci G., Boicu M., "Military Applications of the Disciple Learning Agent," Chapter 8 in Jain L, (ed.), *Advanced Information Systems in Defense and Related Applications*, pp. 337 - 376, Springer Verlag, 2002.
http://lac.gmu.edu/publications/data/2002/2002_9%20Military.pdf
(recommended).