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LEARNING AGENTS LABORATORY

GEORGE MASON UNIVERSITY
Disciple-RKF/COG:
Agent Teaching by Subject Matter Experts
The Summary of the DEMO

About Disciple-COG

Students use of Disciple-COG as a learning assistant
- 1. Specifying a scenario
- 2. Viewing the solutions generated by Disciple
- 3. Generating a center of gravity analysis report

Teaching Disciple-COG by a subject matter expert
- 1. Specifying a training scenario
- 2. Modeling expert’s reasoning
- 3. Task and rule learning
- 4. Rule refinement
- 5. Exception handling
- 6. Problem solving

Tools for the knowledge engineer
- 1. Ontology development tools
- 2. Ontology import tools
About Disciple-COG

Disciple is a theory, methodology, and learning agent shell for rapid development of knowledge bases and agents, by subject matter experts, with limited assistance from knowledge engineers.

The expert teaches Disciple in a way that resembles how the expert would teach a person.

Disciple learns from the expert, building, verifying and improving its knowledge base.

DISCIPLE SYSTEM

- Interface
- Problem Solving
- Learning
- Ontology + Rules
First we will demonstrate how a developed Disciple agent helps the students at the US Army War College to learn about Center of Gravity analysis.

Then, in the main part of the demo, we will show how this Disciple agent was developed by being taught the problem solving method of a military expert.

Finally, we will demonstrate additional tools that are used by the knowledge engineer to perform knowledge base development tasks that are currently beyond the capabilities of a subject matter expert.
Students use of Disciple-COG as a learning assistant

In the “Case Studies in Center of Gravity Analysis” course students learn to identify the centers of gravity (COG) of the opposing forces in military conflicts. The COG of a force is its main source of strength, power, and resistance.

Each student has to study a historic scenario (such as the World War II invasion of the island of Sicily by the Allied Forces) and has to develop a center of gravity analysis report.

Disciple guides the students to specify the relevant aspects of the assigned war scenario. Then it identifies and tests the strategic center of gravity candidates for that scenario, and generates a center of gravity analysis report. The students study and critique the solutions generated by Disciple and finalize the report.
1. Scenario Elicitation

First the student is guided by the scenario elicitation tool to specify the relevant aspects of the war scenario.
1. Scenario Elicitation

The tool shows:

- A table of contents that will be developed during scenario elicitation.
- A list of questions that have to be answered by the student.
1. Scenario Elicitation

The student is asked to provide a short English description of the scenario.
1. Scenario Elicitation

The student is asked to provide a short English description of the scenario.
1. Scenario Elicitation

Disciple assists by providing clarifications for each requested piece of information.

Then the student has to name the opposing forces of the scenario.
1. Scenario Elicitation

Each opposing force is automatically introduced into the table of contents.

When the student selects one of these forces, Disciple asks more specific questions about it.
1. Scenario Elicitation

Because the student has characterized Allied_Forces_1943 as a multi state force, Disciple expands the table of contents with the aspects that are relevant for such a force.
1. Scenario Elicitation

When the student selects one of these aspects, Disciple asks more specific questions about it.
1. Scenario Elicitation

In this way the student is guided to specify the relevant aspects of the scenario.
2. Viewing the solutions generated by Disciple

After the scenario is specified, Disciple can identify and test the corresponding strategic center of gravity candidates.
2. Viewing the solutions generated by Disciple

The tool shows:

The strategic center of gravity candidates for each of the opposing forces

A description of the selected candidate and the rationale for its identification and testing

Summary of Will_of_the_People_of_US_1943 identification

The Will of the People of US 1943 is a strategic COG candidate with respect to the people of US 1943

Summary of Will_of_the_People_of_US_1943 testing as strategic COG

The strategic center of gravity candidates for each of the opposing forces
2. Viewing the solutions generated by Disciple

The solution includes a summary of the specific candidate’s solution.

Summary of Will_of_the_People_of_US_1943 identification

The Will of the People of US 1943 is a strategic COG candidate with respect to the people of US 1943.

Summary of Will_of_the_People_of_US_1943 testing as strategic COG

The Will of the People of US 1943 is a strategic COG candidate that cannot be eliminated.
2. Viewing the solutions generated by Disciple

A justification for the entities selection as a candidate.

Justification of identification for Will_of_the_People_of_US_1943 as COG candidate

- Is Allied_Forces_1943 a single-member force or a multi-member force?
- Allied_Forces_1943 is a multi-member force
- What type of strategic COG candidate should I consider for this multi-member force?
- I consider a candidate corresponding to a member of the multi-member force
- Which is a member of Allied_Forces_1943?
- US_1943
- Is US_1943 a single-member force or a multi-member force?
- US_1943 is a single-member force
- What type of strategic COG candidate should I consider for this single-member force?
- I consider a strategic COG candidate with respect to the people of US_1943
- Is the Will_of_the_People_of_US_1943 a major controlling element of US_1943?
- Yes, because US_1943 is a representative democracy
- Is the Will_of_the_People_of_US_1943 a legitimate candidate?
- Yes

The Will_of_the_People_of_US_1943 is a strategic COG candidate with respect to the people of US_1943
2. Viewing the solutions generated by Disciple

And a summary of the candidates testing.

Justification of testing for Will_of_the_People_of_US_1943 as a strategic COG candidate

- What is the strategic goal of European Axis 1943?
- Dominance of Europe by European Axis

- Assuming that the People of US 1943 would accept the goal of European Axis 1943 which is Dominance of Europe by European Axis, does it have the power to cause the Government of US 1943 to accept that goal?
- Yes, because US 1943 is a representative democracy and the Government of US 1943 reflects the Will of the People of US 1943

- Assuming that the People of US 1943 would accept the goal of European Axis 1943 which is Dominance of Europe by European Axis, does it have the power to cause the Military of US 1943 to accept that goal?
- Yes, because US 1943 is a representative democracy and the Will of the Military of US 1943 reflects the Will of the People of US 1943

The Will of the People of US 1943 is a strategic COG candidate that cannot be eliminated
2. Viewing the solutions generated by Disciple

The justification may be presented in a more abstract form.
2. Viewing the solutions generated by Disciple

Justification of testing for Will_of_the_People_of_US_1943 as a strategic COG candidate

- What is the strategic goal of European Axis 1943?
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- Assuming that the People of US 1943 would accept the goal of European Axis 1943 which is Dominance of Europe by European Axis, does it have the power to cause the Government of US 1943 to accept that goal?
- Yes, because US 1943 is a representative democracy and the Government of US 1943 reflects the Will of the People of US 1943

- Assuming that the People of US 1943 would accept the goal of European Axis 1943 which is Dominance of Europe by European Axis, does it have the power to cause the Military of US 1943 to accept that goal?
- Yes, because US 1943 is a representative democracy and the Will of the Military of US 1943 reflects the Will of the People of US 1943

The Will of the People of US 1943 is a strategic COG candidate that cannot be eliminated.

Or it may be presented in a more detailed form
2. Viewing the solutions generated by Disciple

Or it may be presented in a more detailed form

**Justification of testing for Will_of_the_People_of_US_1943 as a strategic COG candidate**

Test whether the *Will of the People of US 1943* is a viable strategic COG candidate with respect to the people of US 1943

- What is the strategic goal of *European Axis 1943*?
- *Dominance of Europe by European Axis*

Test whether the *Will of the People of US 1943* can cause US 1943 to accept the strategic goal of *European Axis 1943* which is *Dominance of Europe by European Axis*

- Assuming that the *People of US 1943* would accept the goal of *European Axis 1943* which is *Dominance of Europe by European Axis*, does it have the power to cause the *Government of US 1943* to accept that goal?
- Yes, because US 1943 is a representative democracy and the *Government of US 1943* reflects the *Will of the People of US 1943*

Test whether the *Will of the People of US 1943* which controls the *Government of US 1943* can cause US 1943 to accept the strategic goal of *European Axis 1943* which is *Dominance of Europe by European Axis*

Assuming that the *People of US 1943* would accept the goal of *European Axis 1943* which is *Dominance of Europe by European Axis*, does it have the power to cause the *Military of US 1943* to accept that goal?
- Yes, because US 1943 is a representative democracy and the *Will of the Military of US 1943* reflects the *Will of the People of US 1943*
3. Generating a center of gravity analysis report

Then Disciple generates a draft center of gravity analysis report.
3. Generating a center of gravity analysis report

The first part of the report is a description of the scenario which is based on the student’s specification. The student may further improve it by using a text editor.
3. Generating a center of gravity analysis report

The second part of the report is a list of COG candidates and their justifications. The student has to critique Disciple’s reasoning and specify his own justification when in disagreement with Disciple.
Teaching Disciple-COG by a subject matter expert

Now we will discuss how this Disciple agent was developed.

First a knowledge engineer has used the tools of Disciple to build an object ontology that represents the concepts from the COG analysis domain. He has also defined elicitation scripts to guide the user in defining a specific scenario.

After that an expert can teach Disciple his own reasoning in center of gravity analysis, with only limited assistance from the knowledge engineer. The teaching process consists of the sequence of displayed steps and results in a set of problem solving rules learned by Disciple. In the following we will demonstrate this teaching process.
1. Specifying a training scenario

First the expert has to specify a training scenario, by using the Scenario Elicitation tool, as has been illustrated before.

In this illustration we will use the World War II invasion of the island of Okinawa by the US forces.
1. Specifying a training scenario

Based on the information elicited from the expert Disciple creates a formal representation of the scenario.

The internal representation may be viewed using the Association Browser.
2. Modeling expert’s reasoning

Then the expert has to express his reasoning in center of gravity identification and testing for the Okinawa scenario, by using the task reduction paradigm.

I need to

Identify and test a strategic COG candidate for the Okinawa_1945 scenario

What kind of scenario is Okinawa_1945?

Okinawa_1945 is a major theater of war scenario

Therefore I need to

Identify and test a strategic COG candidate for Okinawa_1945 which is a major theater of war scenario

Which is an opposing force in the Okinawa_1945 scenario?

Japan_1945

Therefore I need to

Identify and test a strategic COG candidate for Japan_1945

...
2. Modeling expert’s reasoning

The expert expresses his reasoning process in English, using the Modeling tool of Disciple:

- The modeling tool shows:
  - The entire reasoning tree.
  - The description of the node selected from the reasoning tree.
2. Modeling expert’s reasoning

The first steps of the reasoning process show how the expert has identified Emperor Hirohito as a strategic center of gravity candidate for Japan. We will now show how the expert uses the Modeling tool to express his reasoning of testing whether Emperor Hirohito is a viable candidate.

To reduce the current task the expert needs some information that is identified by asking a question.
2. Modeling expert’s reasoning

To reduce the current task the expert needs some information that is identified by asking a question. Then the expert must provide an answer to this question.

To reduce the current task the expert needs some information that is identified by asking a question.
2. Modeling expert’s reasoning

Then the expert must provide an answer to this question.
2. Modeling expert’s reasoning

Then the expert must provide an answer to this question
2. Modeling expert’s reasoning
2. Modeling expert’s reasoning

The question and its answer lead to this reduction of the top task.
2. Modeling expert’s reasoning

The question and its answer lead to this reduction of the top task.
2. Modeling expert’s reasoning
2. Modeling expert’s reasoning
2. Modeling expert’s reasoning
2. Modeling expert’s reasoning

- Identify and test a strategic COG candidate for the Okinawa_1945 scenario.
- What kind of scenario is Okinawa_1945? (Japan_1945)
- Is Japan_1945 a war scenario?
- Which is an opposing force in the Okinawa_1945 scenario?
- Identify and test a strategic COG candidate for Japan_1945.
- In Japan_1945 a single-member force or a multi-member force?
- Japan_1945 is a single-member force.
- Identify and test a strategic COG candidate for Japan_1945 which is a single-member force.
- What type of strategic COG candidate should I consider for the single-member force?
- I consider a strategic COG candidate with respect to the government of Japan_1945.
- Identify and test a strategic COG candidate with respect to the government of Japan_1945.
- Who or what is a non-controlling element of the government of Japan_1945?
- Emperor_Hirohito that has a critical role in setting objectives and making decisions.
- Identify Emperor_Hirohito as a strategic COG candidate with respect to the government of Japan_1945.
- Is Emperor_Hirohito a legitimate candidate?
- Yes.
- Emperor_Hirohito is a strategic COG candidate with respect to the government of Japan_1945.
- Test whether Emperor_Hirohito is a viable strategic COG candidate with respect to the government of Japan_1945.
- What is the strategic goal of US_1945?
- unconditional_surrender_of_Japan
- Test whether Emperor_Hirohito can cause Japan_1945 to accept the strategic goal of US_1945 which is unconditional_surrender_of_Japan.
- Assuming that Emperor_Hirohito would accept the goal of US_1945 which is unconditional_surrender_of_Japan.
- Yes, because Emperor_Hirohito is the commander in chief of the Military_of_Japan_1945.
2. Modeling expert’s reasoning
2. Modeling expert’s reasoning
2. Modeling expert’s reasoning
2. Modeling expert’s reasoning

This process continues in the same way until the expert has enough information to either eliminate or not eliminate the COG candidate.
2. Modeling expert’s reasoning
3. Task and Rule Learning

We will now demonstrate how Disciple learns general tasks and rules from the expert’s reasoning.
First the expert and Disciple have to formalize the English statements of the tasks.

This is done in the Formalization mode.
3. Task and Rule Learning

In the formalization mode the tool shows:

The modeling in English

The formalized tasks
3. Task and Rule Learning

Disciple will propose a formalization of the task.
3. Task and Rule Learning

Disciple will propose a formalization of the task.

The expert may accept it or he may edit it.
After the tasks are formalized the expert may explain the example to Disciple, which will learn a rule from it.
3. Task and Rule Learning

The Rule Learning tool helps the expert to explain the example to Disciple.

Disciple uses analogical reasoning and other heuristics to propose plausible explanations pieces that justify the task reduction step.

The tool shows the English form of the example.
3. Task and Rule Learning

The expert selects those explanation pieces that correspond to the meaning of the question-answer pair from the task reduction example.
3. Task and Rule Learning

The expert selects those explanation pieces that correspond to the meaning of the question-answer pair from the task reduction example.
3. Task and Rule Learning
3. Task and Rule Learning

Test whether Emperor Hirohito is a viable strategic COG candidate with respect to the government of Japan 1945

What is the strategic goal of US 1945?

unconditional_surrender_of_Japan

Test whether Emperor Hirohito can cause Japan 1945 to accept the strategic goal of US 1945 which is unconditional_surrender_of_Japan

US 1945 -- is-opposed-to --> Japan 1945
Japan 1945 -- is-opposed-to --> US 1945
US 1945 -- has_strategy --> unconditional_surrender_of_Japan
US 1945 <- has_opposing_force --> Emperor 1945 -- has_opposing_force --> Japan 1945
3. Task and Rule Learning

When the expert is satisfied with the identified explanation he can click on “End learning”. Disciple will then create a general rule corresponding to this example and its explanation.

The expert may direct Disciple to generate explanation pieces related to certain objects from the example.
3. Task and Rule Learning

This is the general task reduction rule learned by Disciple.

Notice that it has a plausible upper bound condition and a plausible lower bound condition.

During rule refinement the two conditions will converge toward one another, ultimately leading to a rule with a single condition.
3. Task and Rule Learning

This is the general task reduction rule learned by Disciple.

In addition to the formal structure of the rule, which is used in problem solving and learning, Disciple maintains also an informal structure of the rule.

The informal structure is used in the communication with the user.
3. Task and Rule Learning

After learning a rule from the current task reduction step Disciple returns to the formalization mode.
3. Task and Rule Learning

Following the same procedure, Disciple will learn another rule from the next task reduction step:
3. Task and Rule Learning
3. Task and Rule Learning
3. Task and Rule Learning

Workspace Manager

- Task
  Test whether Emperor Hirohito can cause Japan 1945 to accept the strategic goal of US 1946 which is unconditional_surrender_of_Japan

- Question
  Assuming that Emperor Hirohito would accept the goal of US 1946 which is unconditional_surrender_of_Japan, could Emperor_Hirohito make the Military_of_Japan_1945 accept it?

- Reason
  Yes, because Emperor_Hirohito is the commander in chief of the Military_of_Japan_1945

- Task
  Test whether Emperor Hirohito who controls the Military_of_Japan_1945 can cause Japan 1945 to accept the strategic goal of US 1946 which is unconditional_surrender_of_Japan

- Proposed Explanations
  - Military_of_Japan_1945 -- has_as_commander_in_chief --> Emperor_Hirohito
  - Japan 1945 -- has_as_military_forces --> Military_of_Japan_1945

- Accepted Explanations

End Learning Cancel Learning View Rule
3. Task and Rule Learning

Test whether Emperor Hirohito can cause Japan_1945 to accept the strategic goal of JS_1946 which is unconditional_surrender_of_Japan.

Assuming that Emperor Hirohito would accept the goal of JS_1946 which is unconditional_surrender_of_Japan, could Emperor Hirohito make the Military_of_Japan_1945 accept it?

Yes, because Emperor Hirohito is the commander in chief of the Military_of_Japan_1945.

Test whether Emperor Hirohito who controls the Military_of_Japan_1945 can cause Japan_1945 to accept the strategic goal of JS_1946 which is unconditional_surrender_of_Japan.
3. Task and Rule Learning

- **Task**: Test whether Emperor Hirohito can cause Japan 1945 to accept the strategic goal of US 1945 which is unconditional surrender of Japan.
- **Question**: Assuming that Emperor Hirohito would accept the goal of US 1945 which is unconditional surrender of Japan, could Emperor Hirohito make the Military of Japan 1945 accept it?
- **Answer**: Yes, because Emperor Hirohito is the commander in chief of the Military of Japan 1945.

**Accepted Explanations**
- Japan 1945 -- has_military_force --> Military of Japan 1945
- Military of Japan 1945 -- has_as_commander_in_chief --> Emperor Hirohito

**Proposed Explanations**
- Military of Japan 1945 -- has_military_force --> Military of Japan 1945
- Japan 1945 -- has_military_force --> Military of Japan 1945
3. Task and Rule Learning
3. Task and Rule Learning

Following the same procedure, Disciple will learn another rule from the last task reduction step:
4. Rule Refinement

Disciple uses the partially learned rules in problem solving and refines them based on expert’s feedback.
4. Rule Refinement

Disciple uses the rules learned from the expert’s identification and testing of Emperor Hirohito to identify and test President Truman as a US strategic center of gravity candidate.

The “?” preceding a reasoning step indicates that the step is less plausible, because it is based on the plausible upper bound condition of a learned rule.
4. Rule Refinement

The expert has to examine this step and has to indicate whether it is:

- Correct and completely explained by selecting "Correct Example"
- Correct but incompletely explained by selecting "Explain Example"
- Incorrect by selecting "Incorrect Example"
4. Rule Refinement

The expert has indicated that the reasoning step is correct and Disciple has generalized the plausible lower bound condition of the corresponding rule, to cover this example.
4. Rule Refinement

- In the case of a correct but incompletely explained example, the expert may further explain the example, as has been illustrated before.
- For an incorrect example, the expert has to help Disciple to identify an explanation of why the example is incorrect.
- In all the cases, the rule is automatically refined by Disciple.
5. Exception Handling

Because the object ontology of Disciple is incomplete, it may not contain the knowledge pieces that explain why a certain rule example is incorrect. In such a case the expert has two options:

- **End Rule Refinement** (the incorrect example is kept as a negative exception of the rule; the knowledge base will be extended latter, with the help of the knowledge engineer);

- **Invoke Exception Handling** (the expert attempts to extend the object ontology by himself).

We will demonstrate the handling of exceptions by the subject matter expert.
5. Exception Handling

Disciple generates a task reduction step which is rejected by the expert. The expert and Disciple attempt to find an explanation of why this reasoning step is incorrect. However, there is no ontology piece that explains why this is an incorrect reasoning step.

The expert may end Rule Refining, and Disciple will keep the incorrect reasoning step as a negative exception to the rule that generated it. Or, the expert may start Exception Handling.
5. Exception Handling

The Exception Handling module shows:

- The incorrect reasoning step (the negative exception of the rule)
- An object from the positive example
- The left and right buttons used to view the other objects from the rule’s examples
- The corresponding object from the negative exception of the rule
5. Exception Handling

Disciple generates an ordered list of candidate hypotheses that may distinguish between the positive example and the negative exception of the rule. This is a more detailed description of the candidate highlighted above.

These candidate hypotheses are new ontology pieces (e.g. new feature values, new features, or new objects).

The negative exception may be removed by providing a value for the property “is_mission_oriented” of Military_of_Japan_1945 which is different from the value for Military_of_US_1945.

The expert selects this candidate to remove the exception.
Disciple guides the expert in the definition of new knowledge about the selected candidate.
5. Exception Handling

The expert defines the value of the property “is_mission_oriented” for “Military_of_Japan_1945” in absolute terms and disregard of preserving the lives of its soldiers.

This property value differentiates between the object from the positive example (Military_of_US_1945) and the object from the negative example (Military_of_Japan_1945).
5. Exception Handling

Disciple refines the object ontology and the rule with the elicited feature value.
5. Exception Handling
The automated problem solver presented at the beginning of this demonstration was customized for the Center of Gravity domain.
6. Problem Solving

The Disciple shell also contains a general automated problem solver.
The Disciple shell contains also a suite of knowledge base development tools for the knowledge engineer:

- Ontology browsers and editors to develop the object ontology;
- Ontology import tools to import ontological knowledge for reusable knowledge repositories, such as CYC;
- Script editor to define elicitation scripts;
- More complex exception handling tools for the knowledge engineer.

They will be briefly demonstrated in the following.
1. Ontology Development Tools

- Object Browser
- Object Viewer
1. Ontology Development Tools
1. Ontology Development Tools

- **Object Browser**
- **Script Editor**
2. Ontology import tools

Ontology import tools perform a three step import process:

• Mixed-initiative retrieval of potentially relevant ontological knowledge from external knowledge repositories, such as CYC;

• Automatic translation of the retrieved ontological knowledge into an intermediate Disciple ontology;

• Mixed-initiative import from the intermediate Disciple ontology into the destination Disciple ontology.

The following is a brief demonstration of ontology import from CYC.
2. Ontology import tools

The expert looks for relevant ontological knowledge in CYC

The expert specifies a searching string
2. Ontology import tools

The expert looks for relevant ontological knowledge in CYC.

The expert specifies a search string.

CYC returns all the matching names.

The expert chooses to import “NATO” and the knowledge related to it.
2. Ontology import tools

The knowledge retrieved from CYC is automatically translated into an intermediate Disciple ontology.

<table>
<thead>
<tr>
<th>Concepts</th>
<th>UNITED KINGDOM_OF_GREAT BRITAIN AND NORTHERN IRELAND</th>
<th>SPAIN</th>
<th>GREECE</th>
<th>UNITED STATES OF AMERICA</th>
<th>ITALY</th>
<th>NETHERLANDS</th>
<th>BELGIUM</th>
<th>GERMANY</th>
<th>FRANCE</th>
<th>NORWAY</th>
<th>DENMARK</th>
<th>TURKEY</th>
<th>HUNGARY</th>
<th>PORTUGAL</th>
<th>CANADA</th>
<th>UNION OF SOVIET SOCIALIST REPUBLICS</th>
<th>CZECH REPUBLIC</th>
<th>ICELAND</th>
<th>POLAND</th>
<th>LUXEMBOURG</th>
<th>MODERN MILITARY ORGANIZATION ENTITY</th>
<th>INTERNATIONAL ALLIANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instances</td>
<td>NATO</td>
<td>Statement_of_purpose_considers_as_enemy</td>
<td>International_org-member_country</td>
<td></td>
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</table>

Features whose domains were learned from examples (Such a domain can be either narrower or broader than the original domain):
Statement_of_purpose_considers_as_enemy International_org-member_country

Features whose ranges were learned from examples (Such a range can be either narrower or broader than the original range):
Statement_of_purpose_considers_as_enemy International_org-member_country
2. Ontology import tools

The expert and the knowledge engineer import knowledge from the intermediate Disciple ontology into the destination Disciple ontology.

The objects selected to be imported from the intermediate Disciple ontology into the destination Disciple ontology.

Fragment of the intermediate Disciple ontology translated from CYC.

The expert and the knowledge engineer select the entities to be imported into the destination Disciple ontology.
2. Ontology import tools

The expert and the knowledge engineer import knowledge from the intermediate Disciple ontology into the destination Disciple ontology.

“NATO” is being imported from the intermediate Disciple ontology into the destination Disciple ontology.

The user specifies the additional knowledge to be imported together with “NATO”.

The selected super-concepts of “NATO” will also be imported.

The selected features of “NATO” will also be imported.
2. Ontology import tools

The ontology fragment represented by “NATO”, its super-concepts, and its features is copied into the destination Disciple ontology.

A + denotes a term that does not yet exist in the ontology, while a + denotes an existing term.

The user specifies the position of the imported concepts in the destination Disciple ontology.
2. Ontology import tools

The user updates the feature values
2. Ontology import tools

The import of “NATO” has led to the partial import of these additional objects. Disciple suggests the user to complete their import.

“NATO” is marked as imported in the intermediate Disciple ontology.